

# Psychological Review

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# THE PSYCHOLOGICAL REVIEW

## BREADTH OF LEARNING AS A FUNCTION OF DRIVE LEVEL AND MECHANIZATION<sup>1</sup>

JEROME S. BRUNER, JEAN MATTER, AND MIRIAM LEWIN PAPANEK

*Harvard University*

Suppose a group of rats is trained to respond to the black doors of a four-unit discrimination apparatus, each unit comprising a black and a white door side by side. (See Fig. 1.) And suppose further that these correct doors, during learning, are arranged from trial to trial in a random pattern with respect to whether they are on the left or the right. Under these circumstances, the animals would be learning to respond to the cue of door brightness.

Now suppose, after the animals have learned the black-white discrimination to a criterion, the correct black doors are arranged for a series of trials in a pattern of single alternation. That is, the correct black door is always in the sequence of left-right-left-right. We are interested in finding out how much the animals learn about single alternation during this period when the original black cue is present along with the single-alternation pattern. To test for this learning of the single-alternation pattern, we then remove the black-white discriminanda, inserting gray doors instead, and see how many trials are required for the rats to master the single-alternation pattern to criterion. A control group is required, of course: animals that continue with randomly po-

sitioned black-white training for a number of trials comparable to the series of trials during which experimental animals receive the training with the double cue of black and single alternation.

It would appear at first that such an experiment addresses itself directly to testing predictions that might be derived from the continuity and discontinuity hypotheses about discrimination learning. The continuity hypothesis might hold, to put the matter in somewhat simplified terms, that insofar as reinforcement follows the single-alternation responses during the critical period when black-white cues are still present, then the animal will learn this alternation response even though his original training was to respond to the black doors. Put in more refined terms, reinforcement will lead to the learning of the single-alternation response, provided a sufficient number of reinforced trials has been given. The discontinuity position might hold that insofar as the organism is responding in terms of a black-going hypothesis, it does not learn anything about single alternation during the critical period when the relevant black cue is still present and a black-going hypothesis is adequate for reaching the goal.

The difference between these two classical positions can, we will hold, be reduced to a question about the *range of cues* to which the animal is responding in the course of discrimination

<sup>1</sup> We are indebted to Professor E. C. Tolman for many stimulating suggestions, and to Professors C. F. Mosteller, R. R. Bush, L. Postman, and D. Krech for valuable advice and criticism.

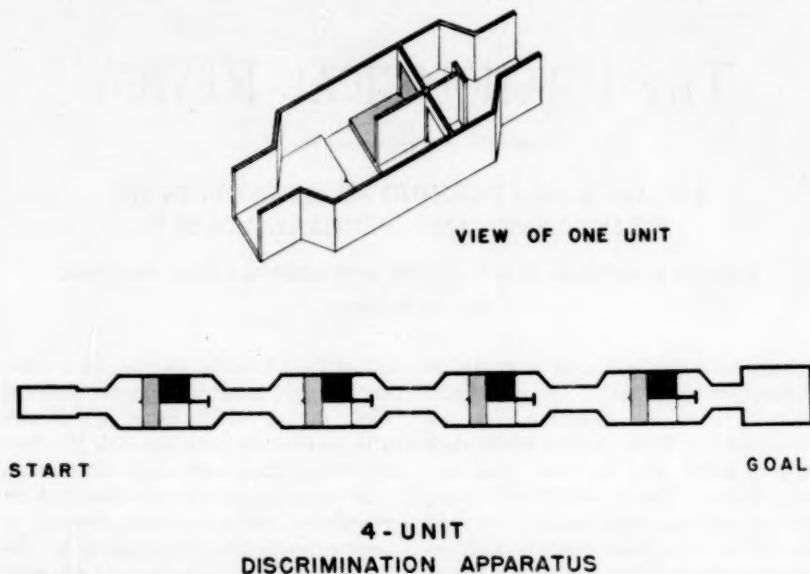


FIG. 1. Four-unit discrimination apparatus (after Greenbaum). Length of each unit is 28 in., maximum width of each unit 9 in., minimum width 4 in. The height of the alleys is 4 in. The entire apparatus is covered by a Plexiglas cover.

learning. The continuity theorem holds the extreme view that this range comprises *all* discriminable cues impinging on the organism during reinforced trials. The discontinuity position holds the equally extreme view that this effective range comprises only *one* set of discriminable cues at a time, or two sets of cues in the event the organism is entertaining a couple of hypotheses simultaneously (12). The continuity position is a theorem derived from stimulus-response reinforcement theory. For reasons that are rather obscure to the present writers, the discontinuity position has often been stated as an integral part of cognitive theory. The question we wish to raise is whether it is necessary for *any* theory of learning to take an axiomatic position on what range of cues is being responded to in a given situation. It is our contention that this is an empirical question, and an important one.

Take stimulus-response reinforcement

theory as a first case in point. Need one assume that reinforcement operates to strengthen response tendencies to *all* discriminable cues present in the situation? As Hull puts it, "According to the 'law of reinforcement' . . . , every one of the receptor discharges and receptor-discharge preservations active at the time that the to-be-conditioned reaction occurs must acquire an increment of habit strength" (9, p. 206). Yet it is known that rats in a jumping-stand situation learn more rapidly to respond to the cues close to the bottom of the card, near the edge to which they are jumping (e.g., Ehrenfreund, 8). And, indeed, it is also well known that a "set" to attend to certain kinds of objects or events in the environment leads to faster and better identification and learning of these than of so-called incidental material—although both kinds of materials are impinging on the organism's sensory apparatus (e.g., Chapman, 6; Postman and Senders, 20).



It will be argued, to be sure, that some stimulus-response theorists have taken the matter into account, the contention being supported by reference to the work of Ehrenfreund (8) and Spence (23). As Ehrenfreund remarks in commenting on the classical "one-cue-at-a-time" discontinuity position, "[continuity] theorists have emphasized the point that the conditions determining reception of the stimulus cues are extremely important" (8, pp. 417-418). He points out that since one must consider the conditions that determine what cues will be "picked up," many of the experiments of the continuity theorists have by-passed the problem by utilizing very simplified discrimination problems, preferring, for example, a simple black-white discrimination rather than pattern discrimination. In a pattern discrimination, "until the S learns the appropriate orienting act that will provide discriminably different retinal patterns of discrimination, the conditions necessary for the development of differential associations do not obtain" (p. 418). Presumably, such orienting acts involve "reception of specific cue aspects of the total stimulus complex on the area of the retina in which the ganglion cells are most dense" (p. 418). This sequence of orientation learning is what Spence calls "the acquisition of receptor exposure adjustments" (23, p. 720).

Indeed, Spence has recognized the importance of this problem. But to reduce the matter at this early stage of investigation to a question of adequate retinal stimulation seems to the present writers somewhat premature. For example, the 15° or 20° of visual arc that separates figures at the middle and at the bottom of a jumping-stand card, shown by Ehrenfreund (8) to matter so much in speed of acquisition of a pattern discrimination, can hardly make that much histological difference in ganglion density in the rat's eye—particularly in view of the amount of VTE

behavior on a jumping stand. Moreover, it seems highly dubious that such a peripheralist explanation would account for what is known about "paying attention to cues" in human subjects. It seems to us that for the moment it is a hindrance to experimental ingenuity to rule out *central* factors that could operate to restrict the range of cues to which an animal is oriented in any given situation. Finally, there are a sufficient number of studies, such as those of Lashley (13) and Snygg (21, 22), to indicate that even when one cue is impinging on the *same* segment of the retina at which another cue is impinging, one may be learned and the other not. Lashley and Wade (14) have made much of this point in criticism of the "all-cues-are-relevant" position, and quite justifiably.

As for cognitive theory, a comparable argument applies. Why should it be axiomatic that while an organism is responding in terms of one cue, he is learning *nothing* about any other cues in the situation? The presence of a "hypothesis" or a systematic response tendency directed to one discriminandum does not necessarily blind the organism to all else. Indeed, the same kind of experiment can be used in evidence against this extreme view as is used against the "all-cues-are-relevant" viewpoint. The subjects in Chapman's experiment (6) *do* pick up features of the stimulus to which they have not been set. Learning of materials *does* occur without a set to learn, as in the Postman and Senders (20) experiment. And, indeed, there is an imposing array of evidence that while responding to one feature of a situation, animals learn about other features of the situation, as indicated by either transfer (e.g., Blum and Blum, 4) or by cue reversal (e.g., McCulloch and Pratt, 16; Ehrenfreund, 8; and various studies reviewed by Melton, 17 and Spence, 23). To hold the one-cue-at-a-time position is to deny, among other things, that there

can be anything approximating a "general set" or "looking around" behavior—a highly restrictive premise for a cognitive theory of learning. Again, we would hold that the number of cues to which the organism attends is not a matter to be settled at the axiomatic level, but should be treated as an empirical problem. It is indeed the case that results by Lashley (13) and by Lashley and Wade (14) are seemingly contradictory to those of Blum and Blum (4), and that Krechevsky (12) can be pitted against McCulloch and Pratt (16). The point is not to establish one set of results *over* the other, but to discover what in one experiment leads organisms to operate on one cue at a time, and, in another, on several at a time.

Krechevsky (12) has, of course, remarked that animals can attend to two cues at a time, as judged from the fact that their behavior can be shown to be simultaneously systematic with respect to two cues. That is, animals could be responding above chance to both a visual and a spatial cue. But his position still implies that the animal is only learning about those aspects of the environment to which it is systematically responding. If it has a double hypothesis, then it is learning only about the two cues involved. We would hold that it is quite unnecessary to *assume* that an organism has to be responding systematically to a cue in order to learn about it—or, for that matter, to assume anything else. The matter is an empirical one.

In sum, we would take the position that a concept like *breadth of learning* would increase the richness of either a cognitive or an S-R theory of learning. By considering breadth of learning as a dependent variable, theorists of either stripe would be more readily disposed to ask the critical question, "What determines breadth of learning or the range of cues about which the organism

picks up information in the course of a particular learning sequence?"

Tolman (27) has addressed himself to this problem in his paper on "Cognitive Maps in Rats and Men" by inquiring into the determinants of broad and narrow cognitive maps. For one of the determinants of a narrow or a broad map is the range of cues utilized by an organism during cognitive acquisition. It would appear that there are several conditions that have the effect of narrowing the range of cues. One of these is motivational level. Tolman suggests, in a manner which he describes as "brief, cavalier, and dogmatic," that excessive motivation or frustration narrows a cognitive map, i.e., reduces the breadth of learning. A better case than suggested by his three deprecatory adjectives can actually be made for his claim. For example, Johnson (10) has recently shown that the degree of learning of the position of an irrelevant reward depends upon the strength of the drive conditions operative during learning. Animals run in a T maze while moderately thirsty and satiated for food learned the position of the food better than animals who were satiated for food but extremely thirsty. Indeed, in the paper by Spence and Lippitt that initiated the Iowa studies of latent learning, the authors suggest that "latent learning does not occur in the situation where the animals 'perceived' the subsequent test goal object (food) while motivated for another goal object (water), but latent learning does occur where complete satiation made for no particular goal directedness in the experimental set-up during the training series" (24, p. 429). Subsequent studies indicate that such an "all-or-none" position is too strongly stated and that animals operating under drive condition can learn the location of an irrelevant reward (e.g., Deisenroth and Spence, 7; Strange, 25; Walker, Knotter, and DeValois, 29; as well as the Johnson study cited above). Thistlethwaite sums up

the evidence by remarking that a reasonable inference from the Spence-Lippitt studies is that "the stronger the drive, the poorer the irrelevant-incentive learning" (26, p. 111). Melton (18), approaching the literature from a different conceptual position, reaches much the same conclusion. The Johnson experiments appear to confirm the generalization, they being the first study systematically to vary drive level in this type of experiment.

Another source of evidence comes from studies of incidental learning and "incidental attention" under conditions of increased incentive. Bahrnick (1), for example, has shown that while intentional learning was faster when the incentive given his human subjects was increased, the amount of incidental learning decreased. In a similar vein, Bahrnick, Fitts, and Rankin (2) have shown that increase in incentive leads to a higher degree of selective attention for those parts of a complex task that subjects interpret as more important, with a concomitant tendency to pay less attention to other features of the situation.

A second condition suggested by Tolman as a narrower of cognitive maps is "an overdose of repetition" (27, p. 261). When an organism has "overlearned" a particular discrimination or problem situation, the effect of this overlearning may be to restrict the range of cues to which the organism attends. Thus, in Luchins' experiment (15), subjects who were given much practice with one kind of solution of a problem are less likely to notice when the same kind of problem can be solved by simpler means. To be sure, the experimental situation employed by Luchins is of such complexity that the effects may be due to many other factors known to be operative in problem solving. In any case, it seems a likely hypothesis that overlearning may operate in the way described.

Another suggestive finding from which

one may infer that mechanization has the effect of narrowing the range of cues responded to is reported by Walker, Knotter, and DeValois (29). Again, using the irrelevant-incentive experimental design with animals running under motivated rather than satiated conditions, they found that animals who developed "strong" position preferences learned less about the location of the irrelevant incentive than those with weak position preference. Thistlethwaite (26) notes that in at least three of the experiments reporting no learning of the position of an irrelevant incentive the animals had acquired strong positional preferences during initial training (Kendler, 11; Spence and Lippitt, 24; Walker, 28). We are interpreting strong positional preferences as indicative of mechanization of behavior of a sort also produced by overlearning.

#### AN ILLUSTRATIVE EXPERIMENT

Now let us return to the experiment mentioned briefly in the introductory paragraphs of this paper. Breadth of learning will be denoted operationally in this experiment as the learning of single alternation while responding systematically to door brightness. What might favor such "breadth of learning"? We propose to test two possible factors: strength of motivation and degree of overlearning. Highly motivated animals should show less breadth of learning than moderately motivated ones. Animals overtrained on the original black-white discrimination should be less likely to pick up the single-alternation cue when it is introduced. For good measure, highly motivated and overtrained animals should show the least breadth of learning in the sense of being least able to pick up and use the added single-alternation cue.

*Method.* The design of the experiment is readily summarized. Fifty-two mature male albino rats were divided into four experimental groups and four matching control groups, each group consisting of from six to eight

animals. The experimental groups were all trained to certain levels of performance on a four-unit black-white discrimination apparatus to go either to black or to white. (See Fig. 1.) The correct doors, during this black-white learning, were always in a random pattern with respect to left-right position, with the restriction that the correct door was equally often on the right and the left on each trial. The animals were then given 20 trials of training in which the correctly colored doors were always in a single-alternation pattern, half of the animals going left-right-left-right, the other half right-left-right-left. The control groups received the same original black-white discrimination training on randomly positioned black and white doors and during the 20 critical trials were continued, as before, on the same random-position black-white discrimination. The experimental groups that received both black-white and single-alternation cues during the critical period we shall call the Double-Cue groups. The control animals we shall refer to as Single-Cue groups.

After the critical 20 trials, all animals were trained to criterion on a single-alternation pattern with uniform gray doors at each choice point in the four-unit apparatus.

The four experimental or Double-Cue groups, each with its corresponding control or Single-Cue group, were subjected to the following treatments:

1. *Learn-12-hr. deprived.* Thirty trials of black-white training before critical 20 trials. Twelve-hour food deprivation.

2. *Learn-36-hr. deprived.* Thirty trials of black-white training before critical 20 trials. Thirty-six-hour food deprivation.

3. *Overlearn-12-hr. deprived.* One hundred trials of black-white training before critical 20 trials. Twelve-hour food deprivation.

4. *Overlearn-36-hr. deprived.* One hundred trials of black-white training before critical 20 trials. Thirty-six-hour food deprivation.

The initial 30 trials of black-white training were sufficient to bring all animals to a criterion of 100 per cent on ten successive trials. This apparently small number of trials is not surprising, since the animals make four discriminations on each trial. Thus, the critical trials, whether single-cue or double-cue, were run in all instances with the animal making virtually no errors at all. Training on single alternation with gray doors was carried on at the same level of motivation used for the animal during black-white training and during the critical trials.

Animals were run ten trials per session and the sessions were separated by a 48-hr. period. After each trial, an animal was allowed to feed in the goal box on a rich wet mash

for 10 to 15 sec. After running its ten trials, it was fed away from its home cage for 30 min. All animals were next fed 12 hr. later, again for 30 min. The harshly deprived group was not fed outside the apparatus again until the animals had completed their next set of ten trials 36 hr. later. Moderately deprived animals were fed once more before their next trials, 12 hr. later. Water was available to the rats at all times.

**Results.** Recall the first question. Will animals learn the single-alternation pattern during the critical period when they are responding effectively to door color? A comparison of pooled Double-Cue groups and pooled Single-Cue groups (Table 1) indicates that in the first ten trials of gray-door, single-alternation training Double-Cue groups made 8.0 errors and Single-Cue groups made 12.0 errors. An error, of course, is attempting to get through the wrong door in any unit. The difference in errors is significant at the .005 level. Thus we may conclude that the Double-Cue animals do pick up information about the "incidental cue." The finding conforms in general terms to those reported by Blum and Blum (4).

We come now to the test of the two factors that might limit breadth of learning. Consider degree of original learning of the black-white discrimination prior to the double-cue period. The Double-Cue animals that learned to criterion show a highly significant savings as compared to their Single-Cue controls (Table 1). The Double-Cue animals that underwent original overlearning do not do significantly better than their controls.

With respect to motivation, Double-Cue animals that operated under 12-hr. deprivation conditions do significantly better than their Single-Cue controls. But Double-Cue animals that operate under 36-hr. deprivation do not do better than their controls (Table 1).

Finally, treating each of the four conditions separately, we find the Double-Cue animals that learned to criterion and operated at 12 hr. of deprivation

TABLE 1

MEAN NUMBER OF ERRORS AND SAVINGS ON  
FIRST TEN TRIALS OF SINGLE ALTERNATION  
WITH GRAY DOORS  
(Chance performance [50%] is 20 errors)

Group	Single Cue	Double Cue	Savings	t-Test Reliability*
All animals	12.0	8.0	4.0	<.005
Learn to criterion	12.9	7.4	5.5	<.005
Overlearn	10.9	8.7	2.3	N.S.
12-hr. deprived	12.6	7.8	4.8	.01
36-hr. deprived	11.4	8.2	3.2	N.S.
Learn-12 hr.	13.6	7.8	5.8	.025
Learn-36 hr.	12.3	6.8	5.5	<.05
Overlearn-12 hr.	11.5	7.8	3.7	N.S.
Overlearn-36 hr.	10.3	9.5	.8	N.S.

\* Confidence levels are for a one-tailed test.

doing best in comparison with their controls; the overlearned, 36-hr. deprived animals do least well in comparison with their control group. An analysis of these group results suggests that overlearning has a more marked narrowing effect than high drive.

A word about the Single-Cue groups is in order. A comparison of the figures in Table 1 shows that overlearned animals learn a new task somewhat faster than ones with less prior training, a fact probably attributable to maze-wiseness. Similarly, highly motivated Single-Cue animals learn single alternation faster than moderately motivated ones. None of the differences among the Single-Cue groups is, however, significant.

Are there any observable features of the overt responses of animals who, during the critical period, pick up the alternation cue as compared with their less "observant" fellows? The first and most obvious difference to look for is in the number of vicarious-trial-and-error responses (VTE's) made by animals in those groups given the double cue during the critical trials. Table 2 contains such a comparison. Since the apparatus contains four choice points, the maximum number of VTE's possible during the 20 critical trials is 80, only one VTE being counted per choice point.

Comparing the groups found before to be at the extremes on savings, we find that the group with the largest saving (Learn-12-hr. deprived) showed the greatest amount of VTE, while the group with the smallest saving (Overlearn-36-hr. deprived) showed the least VTE. The former made VTE responses on the average at half the choice points encountered, the latter at a quarter of the choice points. The other groups were between these in frequency of VTE. An analysis of variance of number of VTE's during the critical trials reveals that degree of motivation is significant at the .05 level, and amount of learning falls slightly short of significance at this confidence level.

Another possible difference between the groups is in speed of running during the 20 critical trials. Here the argument is somewhat ambiguous. In a visual task, it might be argued, speed might lead the animal to "overlook" cues. But the extra cue provided during the critical period was a positional one: single alternation. It might be argued that fast running would give better kinesthetic cues for picking up single alternation. In any case, the data on running speed are quite unrevealing. As might be expected, the more highly motivated animals ran the maze more quickly. On the other hand, those animals with initial overlearning

TABLE 2

AVERAGE NUMBER OF VTE RESPONSES  
DURING 20 CRITICAL TRIALS IN ANIMALS  
OF THE GROUPS GIVEN THE DOUBLE-  
CUE TREATMENT

(Maximum number of VTE's possible is 80)

Group	No. of VTE's
Learn-12-hr. deprived	40.2
Learn-36-hr. deprived	27.8
Overlearn-12-hr. deprived	29.5
Overlearn-36-hr. deprived	21.8
Combined Learn	34.0
Combined Overlearn	25.6
Combined 12-hr. deprived	34.9
Combined 36-hr. deprived	24.8



of the black-white discrimination were slower than the group with initial learning to criterion. Thus, one factor associated with failure to pick up the extra cue (high motivation) is associated with fast running, the other (overlearning) with slow running.

#### DISCUSSION AND CONCLUSION

We would propose as a first and most general conclusion that there are conditions that lower the likelihood that an organism will attend to or acquire knowledge about environmental cues not immediately relevant to the to-be-reinforced responses he is making. Breadth of learning can fruitfully be treated as a dependent variable, and two conditions affecting it have been proposed: overlearning and overmotivation.

Beyond this, the question arises as to the nature of the effect: What mediates breadth of learning? In an earlier section, the proposal was made that a peripheralist explanation in terms of the organism orienting his relevant receptors to the stimulus would be premature. In the present experiment, the rats were peripherally exposed to the second or extra cue that they were to be tested on later. At least there is no basis for saying that the alternating kinesthetic pattern was not registering on appropriate receptors. A glance at Fig. 1 suffices to recognize that the apparatus was designed in a way to guarantee weaving about. Our conclusion must be that a peripheral sensory stimulus may or may not be utilized in discrimination learning, depending upon the operation of certain internal processes. In view of this, the axiomatic position of continuity theory that *all* cues present when a response is reinforced are relevant seems no more justified than the axiomatic position of discontinuity theory that only the *one* cue toward which the organism has a hypothesis is relevant.

What of the effect of motivation and mechanization on breadth of learning? Information analyses of recognition and

identification phenomena have made it clear that the larger the number of alternative cues for which the organism is set, the greater the difficulty involved in recognizing any one of them upon its appearance. Thus, Miller, Heise, and Lichten (19) and Bruner, Miller, and Zimmerman (5) have shown that the larger the number of alternative words expected in an auditory articulation test, the greater the signal-to-noise ratio necessary in order for each of the same words to be recognized. Miller, Postman, and Bruner (18) have shown that an increase in independent alternatives requires an increase in exposure duration for visual identification to occur.

Now, the more pressing the requirement that an organism reach a goal rapidly, the more hindering will be a set for considering many alternative cues. Thus, to speed up goal attainment, an organism sacrifices breadth of attention and consequently breadth of learning.

Extreme motivation impelling an organism to the attainment of a specific goal may provide almost a paradigm of the kind of adjustive requirement that compels speed and efficiency with respect to minimal cues. Thus, we can summarize the matter by saying that strong motivation has the effect of speeding up learning at the cost of narrowing it.

As for "a dose of overlearning," as Tolman (27) calls one of the conditions for producing a narrow cognitive map, its effect may also be to restrict cue utilization in a given situation so that new cues introduced after stabilization has occurred are not as likely to be utilized. Why or how the range of cues utilized should be restricted in overlearning is not clear. There is fair evidence that it is. Generalization gradients under repeated classical conditioning narrow (3); and it is a matter of common sense observation that when performance of a particular task becomes mechanized, we "fall into a set" and may fail to notice that the situa-

tion has changed, as in the Luchins experiment mentioned earlier (15).<sup>2</sup>

By way of general conclusion, three points deserve emphasis:

1. It is fruitless to take an axiomatic position about the range of cues that an organism will utilize in making a discrimination. The range of cues utilized, or attended to, or associated with a response, is a function of determinate processes and should be treated empirically as a dependent variable. We have called this variable *breadth of learning*.

2. Conditions requiring increased speed and efficiency of goal attainment by an organism may have the effect of narrowing the range of environmental cues to which the organism responds. High motivation and intensive practice are known to increase the specific efficiency of learning. Yet these are the very conditions that appear to narrow the breadth of learning. In short, the picture given by such traditional measures as latency, speed, and even errors fails to encompass a critical aspect of learning: how much about the environment is the organism picking up over and beyond what is required by the task at hand?

3. If the variable we have called breadth of learning is to take its place beside other traditional learning variables such as those mentioned above, it is necessary to devise experimental paradigms for its measurement. Two such paradigms already exist. The first is the "cue reduction" procedure in which an array of relevant cues is provided in

the original learning and, in later test situations, is systematically reduced in number. A more efficient variant is to establish discrimination on the basis of one set of cues and then to introduce additional cues, finally removing the original cues in the testing situation. This procedure has been used by Lashley (13), Blum and Blum (4), Greenbaum,<sup>3</sup> and by us in the present experiment. A third technique involves devising situations in which the actual utilization of cues can be observed. Counting the number of VTE responses is one way of approximating this procedure. Thus, in the present experiment, it was found that the moderately motivated animals and those not receiving overlearning trials showed the greatest amount of VTE during the critical trials when both cues were present. Wyckoff (30) has recently introduced an ingenious and direct way of observing cue utilization. Using the homogeneous environment of a Skinner box, he required of his pigeons that they press on a lever in order to have the relevant discriminanda appear. Without these discriminanda the birds could not press the food-delivery lever at a level better than chance. Wyckoff was able, by this means, to study the growth of single-cue utilization under a variety of conditions. It would be relatively easy to extend the technique to a multiple-cue experiment.

Finally, and almost as a postscript, it seems somehow ironic that psychologists for the most part have neglected an aspect of learning—call it breadth, perspective, or what you will—that is so much a feature of our instructional lives. We constantly seek to create the conditions in which our students will grasp the many and varied aspects of the phenomena to which we are introducing them. Yet in our theories of learning we have taken the side of the hedgehog in the classic line, "The fox

<sup>2</sup> On the other hand, it may be pointed out that mechanization of a performance may have the effect of "freeing" the individual to notice those aspects of his environment not directly related to his task—may indeed broaden learning. The highly skilled skier, for example, is more likely to notice features of the landscape not related to his immediate task of descending a slope than is the novice—assuming equal motivation. There is obviously an additional variable, or variables, operating in overlearning that is still largely unknown to us.

<sup>3</sup> Greenbaum, J. Personal communication, 1953.

knows many things, but the hedgehog knows one thing."

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## A THEORY OF DISCRIMINATION LEARNING<sup>1</sup>

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This paper presents a theory of two-choice discrimination learning. Though similar in form to earlier theories of simple learning by Estes (5) and Bush and Mosteller (2,3), this system introduces a powerful new assumption which makes definite quantitative predictions easier to obtain and test. Several such predictions dealing with learning and transfer are derived from the theory and tested against empirical data.

The stimulus situation facing a subject in a trial of discrimination learning is thought of as a set of cues. A subset of these cues may correspond to any thing—concrete or abstract, present, past, or future, of any description—to which the subject can learn to make a differential response. In this definition it does not matter whether the subject actually makes a differential response to the set of cues as long as he has the capacity to learn one. An individual cue is thought of as “indivisible” in the sense that different responses cannot be learned to different parts of it. Informally, the term “cue” will occasionally be used to refer to any set of cues, all of which are manipulated in the same way during a whole experiment.

<sup>1</sup>This paper is adapted from part of a Ph.D. dissertation submitted to Stanford University. The author is especially indebted to Dr. Douglas H. Lawrence and to Dr. Patrick Suppes for encouragement and criticism. Thanks are also due Dr. W. K. Estes who loaned prepublication manuscripts and Dr. R. R. Bush who pointed out some relations between the present theory and the Bush-Mosteller model (3).

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In problems to be analyzed by this theory, every individual cue is either “relevant” or “irrelevant.” A cue is relevant if it can be used by the subject to predict where or how reward is to be obtained. For example, if food is always found behind a black card in a rat experiment, then cues aroused by the black card are relevant. A cue aroused by an object uncorrelated with reward is “irrelevant.” For example, if the reward is always behind the black card but the black card is randomly moved from left to right, then “position” cues are irrelevant. These concepts are discussed by Lawrence (6).

In experiments to be considered, the subject has just two choice responses. No other activities are considered in testing the theory. Any consistent method of describing these two responses which can be applied throughout a complete experiment is acceptable in using this theory.

### THEORY

In solving a two-choice discrimination problem the subject learns to relate his responses correctly to the relevant cues. At the same time his responses become independent of the irrelevant cues. These two aspects of discrimination learning are represented by two hypothesized processes, “conditioning” and “adaptation.”

Intuitively, a conditioned cue is one which the subject knows how to use in getting reward. If  $k$  is a relevant cue and  $c(k,n)$  is the probability that  $k$  has been conditioned at the beginning of the  $n$ th trial, then

$$c(k,n+1) = c(k,n) + \theta[1 - c(k,n)] \quad [1]$$

is the probability that it will be conditioned by the beginning of the next trial. On each trial of a given problem a constant proportion,  $\theta$ , of unconditioned relevant cues becomes conditioned.

To the extent that a conditioned cue affects performance, it contributes to a correct response only, whereas an unconditioned relevant cue contributes equally to a correct and to an incorrect response.

Intuitively, an adapted cue is one which the subject does not consider in deciding upon his choice response. If a cue is thought of as a "possible solution" to the problem, an adapted cue is a possible solution which the subject rejects or ignores. If  $a(k, n)$  is the probability that irrelevant cue  $k$  has been adapted at the beginning of the  $n$ th trial, then

$$a(k, n+1) = a(k, n) + \theta[1 - a(k, n)] \quad [2]$$

is the probability that it will be adapted by the beginning of the next trial. On each trial of a given problem a constant proportion of unadapted irrelevant cues becomes adapted. An adapted cue is non-functional in the sense that it contributes neither to a correct nor to an incorrect response.

It will be noticed that the same constant  $\theta$  appears in both equations 1 and 2. The *fundamental simplifying assumption* of this theory deals with  $\theta$ . This assumption is that

$$\theta = \frac{r}{r+i}, \quad [3]$$

where  $r$  is the number of relevant cues in the problem and  $i$  is the number of irrelevant cues. Thus,  $\theta$  is the proportion of relevant cues in the problem. This proportion is the same as the fraction of unconditioned cues conditioned on each trial, and the

fraction of unadapted cues adapted on each trial.

The performance function  $p(n)$ , representing the probability of a correct response on the  $n$ th trial, is in accord with the definitions of conditioning and adapting given above. The function is in the form of a ratio, with the total number of unadapted cues in the denominator and the number of conditioned cues plus one-half times the number of other cues in the numerator. Thus conditioned cues contribute their whole effect toward a correct response, adapted cues contribute nothing toward either response, and other cues contribute their effect equally toward correct and incorrect responses. Formally,

$$p(n) = \frac{\sum_r c(k, n) + \frac{1}{2} \sum_r [1 - c(k, n)] + \frac{1}{2} \sum_i [1 - a(k, n)]}{r + \sum_i [1 - a(k, n)]} \quad [4]$$

Here  $\sum_r$  is the sum taken over the  $r$  relevant cues and  $\sum_i$  is the sum taken over the  $i$  irrelevant cues.

#### SOME CONSEQUENCES REGARDING SIMPLE LEARNING

If the subject is naive at the beginning of training, so that for any relevant cue  $k$ ,  $c(k, 1) = 0$ , and for any irrelevant cue  $k$ ,  $a(k, 1) = 0$ , and if he receives  $n$  trials on a given problem, then by mathematical induction it can be shown that if  $k$  is relevant,

$$c(k, n+1) = 1 - (1 - \theta)^n \quad [5]$$

and if  $k$  is irrelevant,

$$a(k, n+1) = 1 - (1 - \theta)^n. \quad [6]$$

Under these circumstances we can substitute equations 5 and 6 into equation 4 and, taking advantage of



the simplifying effects of equation 3, we have

$$p(n) = 1 - \frac{1}{2} \frac{(1 - \theta)^{n-1}}{\theta + (1 - \theta)^n}. \quad [7]$$

Plotting equation 7 shows that  $p$  is an S-shaped function of  $n$  with an asymptote (for  $\theta > 0$ ) at 1.00. Also,  $p(1) = \frac{1}{2}$ . Since  $p(n)$  is a monotonic increasing function of  $\theta$  we can estimate  $\theta$  from observations of performance. If we want to know the theoretical proportion of relevant cues in a problem for a particular subject, we have the subject work on the problem, record his performance curve, and solve equation 7 for  $\theta$ . This result depends directly upon the simplifying assumption of equation 3.

Since the instability of individual learning curves makes it difficult to fit curves to them, it is fortunate that  $\theta$  can be determined in a different way. Suppose a subject makes  $E$  errors in the course of solving the problem to a very rigorous criterion and it is assumed for practical purposes that he has made all the errors he is going to make. Theoretically, the total number of errors made on a problem can be written

$$E = \sum_{n=1}^{\infty} [1 - p(n)].$$

Under the conditions satisfying equation 7, this can be evaluated approximately by using the continuous time variable  $t$  in place of the discrete trial variable  $n$ , and integrating. The result of this integration is that

$$E \simeq \frac{1}{2} + \frac{1}{2} \frac{\log \theta}{(1 - \theta) \log (1 - \theta)}. \quad [8]$$

By equation 8, which relates the total number of errors made on a problem to  $\theta$ , it is possible to make relatively stable estimates of  $\theta$ .

#### AN EMPIRICAL TEST OF THE SIMPLE LEARNING THEORY—COMBINATION OF CUES

Consider three problems,  $s_1$ ,  $s_2$ , and  $s_3$ , all of which involve the same irrelevant cues. Two of the problems,  $s_1$  and  $s_2$ , have entirely separate and different relevant cues, while in problem  $s_3$  all the relevant cues of  $s_1$  and  $s_2$  are present and relevant. That is,  $r_3 = r_1 + r_2$  and  $i_1 = i_2 = i_3$ . If we know  $\theta_1$  and  $\theta_2$  we can compute  $\theta_3$ , since by equation 3

$$\theta_1 = r_1 / (r_1 + i)$$

$$\theta_2 = r_2 / (r_2 + i)$$

$$\theta_3 = (r_1 + r_2) / (r_1 + r_2 + i).$$

Solving these equations for  $\theta_3$  in terms of  $\theta_1$  and  $\theta_2$  we get

$$\theta_3 = (1 - \theta_1)(1 - \theta_2) / (1 - \theta_1\theta_2). \quad [9]$$

This theorem answers the following question: Suppose we know how many errors are made in learning to use differential cue  $X$  and how many are used to learn cue  $Y$ , then how many errors will be made in learning a problem in which either  $X$  or  $Y$  can be used (if  $X$  and  $Y$  are entirely discrete)?

Eninger (4) has run an experiment which tests equation 9. Three groups of white rats were run in a T maze on successive discrimination problems. The first group learned a visual discrimination, *black-white*, the second group learned an auditory discrimination, *tone-no-tone*, and the third group had both cues available and relevant.

Since each group was run to a rigorous criterion, total error scores are used to estimate  $\theta_1$  and  $\theta_2$  by equation 8.<sup>3</sup> The values estimated are

<sup>3</sup>Total error scores do not appear in Eninger's original publication and are no longer known. However, trials-to-criterion scores were reported. Total error scores were

$\theta_1 = .020$ , based on an estimated average of 98.5 errors made on the auditory-cue problem, and  $\theta_2 = .029$ , based on an estimated average of 64.5 errors on the visual-cue problem. Putting these two values into equation 9 we get

$$\theta_3 = .029 + .020 + \frac{2(.020)(.029)}{1 - (.020)(.029)} \\ = .049.$$

This value of  $\theta_3$  substituted into equation 8 leads to the expectation of about 33 total errors on the combined cues problem. In fact, an average of 26 errors was made by the four subjects on this problem. The prediction is not very accurate. However, only 14 animals were employed in the entire experiment, in groups of five, five, and four. Individual differences among animals within groups were considerable. If account is taken of sampling variability of the two single-cue groups and of the combined-cue group of subjects, the prediction is not significantly wrong. Further experimentation is needed to determine whether the proposed law is tenable.

It is easily seen that  $\theta_3$  will always be larger than  $\theta_1$  or  $\theta_2$  if all three problems are solved. Learning will always be faster in the combined-cues problem. Eninger (4) in his paper points out that this qualitative statement is a consequence of Spence's theory of discrimination. However, Spence's theory gives no quantitative law.

#### TRANSFER OF TRAINING

In order to apply this theory to transfer-of-training experiments in which more than one problem is used, certain assumptions are made. It is

estimated from trials-to-criterion scores by using other, comparable data collected by Amsel (1). Dr. Amsel provided detailed results in a personal communication.

assumed that if a cue is conditioned in one problem and appears immediately thereafter as a relevant cue in a new problem, it is still conditioned. Likewise, an adapted cue appearing as an irrelevant cue in a new problem is adapted. However, if a conditioned cue is made irrelevant it is obviously no longer conditioned, since it cannot serve as a predictor of reward. Similarly, it is assumed that if an adapted cue is made relevant in a new problem, it becomes unadapted and available for conditioning.

According to the present definition of conditioning, a conditioned cue contributes to a correct response. Therefore the above assumptions will not hold if the relation between a cue and a reward is reversed in changing the problem. This theory cannot be used to analyze reversal learning, and is applicable only in cases in which relevant cues maintain an unchanging significance.

If two problems are run under the same conditions and in the same apparatus, and differ only in the degree of difference between the discriminanda (as where one problem is a *black-white* and the other a *dark gray-light gray* discrimination), it is assumed that both problems involve the same cues; but the greater the difference to be discriminated, the more cues are relevant and the less are irrelevant.

#### EMPIRICAL TESTS OF THE TRANSFER-OF-TRAINING THEORY

As Lawrence (7) has pointed out, it seems that a difficult discrimination is more easily established if the subjects are first trained on an easy problem of the same type than if all training is given directly on the difficult discrimination. The experimental evidence on this point raises the question of predicting transfer per-

formance from one problem to another, where the two problems involve the same stimulus dimension but differ in difficulty.

Suppose that problems  $s_1$  and  $s_2$  both require a discrimination along the same stimulus dimension and differ only in that  $s_2$  is more difficult than  $s_1$ . Let  $\theta_1$  be the proportion of relevant cues in problem  $s_1$  and  $\theta_2$  be the proportion of relevant cues in  $s_2$ . Suppose that the training schedule involves  $n$  trials on problem  $s_1$  followed by  $j$  trials on problem  $s_2$ . Then the probability of a correct response on trial  $n + j$  is

$$p(n + j) = \frac{\theta_2 + \frac{1}{2}(1 - \theta_2)^{j-1}[\theta_1 - \theta_2 + (1 - \theta_1)^n(1 - \theta_1 - \theta_2)]}{\theta_2 + (1 - \theta_2)^{j-1}[\theta_1 - \theta_2 + (1 - \theta_1)^{n+1}]} \quad [10]^4$$

This theorem can be tested against the results of experiments reported by Lawrence (7). He trained white rats in one brightness discrimination and transferred them to a more difficult problem for further training. A control group, which Lawrence called "HDG," learned the hard test problem without work on any other problem. The performance of this control group is used to estimate  $\theta_2$ , the proportion of relevant cues in the test problem. The value found was .04.<sup>5</sup> Since the experimental subjects first worked on the pretraining prob-

lem without prior experience, their performance on the first problem serves to estimate  $\theta_1$ , the proportion of relevant cues in the easier pretraining problem. Lawrence replicated the experiment, having two experimental groups, ATG No. 1 and ATG No. 2, each of which transferred abruptly from an easy pretraining problem to the test problem. Group ATG No. 1 had a very easy problem for which we estimate  $\theta_1 = .14$ . Group ATG No. 2 had a more difficult problem for which  $\theta_1' = .07$ .

For group ATG No. 1,  $\theta_1 = .14$ ,  $\theta_2 = .04$ , and  $n = 30$  since thirty

trials of pretraining were given. From this information we can compute  $p(n + j)$  for all  $j$ , using equation 10. The predicted transfer performance is compared with observed performance in Table 1. For group ATG No. 2,  $\theta_1' = .07$ ,  $\theta_2 = .04$ , and  $n = 50$  since fifty trials of pretraining were given. Here also,  $p(n + j)$  can be computed. Prediction is compared with observed performance in Table 1, from which it can be seen that the predictions are

TABLE 1  
PREDICTION OF EASY-TO-HARD TRANSFER  
IN RATS\*

Trials of Transfer Training	Proportion of Correct Responses			
	Group ATG 1		Group ATG 2	
	Observed	Predicted	Observed	Predicted
1-10	.66	.63	.81	.71
11-20	.70	.68	.83	.77
21-30	.74	.72	.81	.81
31-40	.84	.78		
41-50	.86	.83		

\* Data from Lawrence (7).

<sup>4</sup> The justification of equation 10 involves no mathematical difficulties. On the first trial of transfer we know the probability that any cue relevant in the second problem is conditioned, since all cues relevant in the second problem were relevant in the first. Similarly, we know the probability that  $i_1$  of the  $i_2$  irrelevant cues are adapted. The other  $i_2 - i_1$  cues are unadapted. Equations 1 and 2 can be applied at this point, and all terms divided by  $r_1 + i_1 (= r_2 + i_2)$ .

<sup>5</sup> These estimates were made by the unsatisfactory method of fitting equation 7 to group average learning curves. Therefore the results regarding Lawrence's experiment are approximate.

relatively accurate, though performance is higher than predicted.

Lawrence also considered the possibility that a gradual transition from easy through successively harder problems would result in rapid mastery of the difficult problem. He tested this proposition by giving another group of subjects a series of three pretest problems before the final test problem. The problems in order of ease of learning were, first, the problem learned by ATG No. 1 with  $\theta_1 = .14$ , an intermediate problem which was not otherwise used, the difficult pretest problem with  $\theta_3 = .07$ , and finally the test problem with  $\theta_4 = .04$ .

To estimate  $\theta_2$  in Lawrence's experiment where problem  $s_2$  never was used separately in simple learning, we notice the relation of  $\theta$  to differences between discriminanda in apparent foot-candles for problems  $s_1$ ,  $s_3$ , and  $s_4$  whose  $\theta$  values are known. We know that if the problems are properly controlled, and the stimulus difference is zero foot-candles, there are no relevant cues and  $\theta$  is zero. It was found that this assumption, along with available data, made it possible to write a tentative empirical function relating  $\theta$  to the difference between discriminanda in foot-candles. This equation presumably holds only in the case of Lawrence's apparatus, train-

TABLE 2  
THE RELATION OF "DIFFERENCE BETWEEN STIMULI" AND  $\theta$  VALUE OF PROBLEM\*

Difference Between Discriminanda in Apparent Foot-Candles	Corresponding $\theta$ Value of Problem
67.7	.14
35.2	.113**
14.0	.07
5.9	.04
0.0	.00†

\* Data from Lawrence (7).

\*\* Estimated by interpolation from empirical equation 16.

† Theoretical—see text for explanation.

TABLE 3  
PREDICTION OF TRANSFER PERFORMANCE OF RATS AFTER A SERIES OF PRETRAINING PROBLEMS\*

Trials Working on Final Test Problem	Proportion of Correct Responses	
	Observed	Predicted
1-10	.73	.73
11-20	.82	.79
21-30	.87	.84
31-40	.89	.87
41-50	.90	.90

\* Data from Lawrence (7).

ing procedure, subjects, etc. The equation adopted is

$$\theta = .0988 \log_{10}(4d) \quad [11]$$

where  $d$  is the difference between discriminanda in foot-candles. It is emphasized that this equation has no theoretical significance and is merely expedient. From equation 11 it is possible to determine the  $\theta$  value of the intermediate pretraining problem by interpolation. Table 2 gives the data and results of this interpolation.

Ten trials were given on each of the first three problems and fifty trials on the final test problem. Using the  $\theta$  values in Table 2 it is possible to predict the test problem performance of subjects who have gone through gradual transition pretraining.<sup>6</sup> This prediction is compared with observed performance in Table 3. It may be noted that the correspondence between prediction and observation is in this case very close. Again, however, the prediction is consistently a little lower than observed performance.

\* The general prediction for transfer through a series of problems which get successively more difficult can be derived by following through and repeating the reasoning in footnote 4. Since the resulting equations are extremely large and can be derived rather easily, they are not given here.

## NEW DATA

The theory has thus far been tested against the behavior of rats. Its generality is now tested with college students in a simple discrimination learning task.

*Subjects and procedure.* The subjects in this experiment were 23 students in the elementary psychology course at Stanford University. The *S* was seated at one end of a table and told that his responses could be either "A" or "B". On each trial *S* saw a single stimulus, which was a black square on a circular white background. The two squares used on alternate trials differed in size. In problem *s*<sub>1</sub> the squares differed in height by  $\frac{1}{4}$  in., in problem *s*<sub>2</sub> they differed by  $\frac{1}{4}$  in. The mean height of each pair of squares was 3 in. The squares were viewed at a distance of about 6 ft.

For half the *S*s in each experimental group, the problem was to say "A" to the smaller square and "B" to the larger one. The other *S*s had the converse problem. The *S* was never told that the problem was a size discrimination. Stimuli were alternated randomly. A rest period was called after each ten trials and *S* was asked what he thought the correct solution to the problem was, and to outline possible solutions which had occurred to him. This method of questioning is a modification of Prentice's method (8).

Twelve *S*s were trained first on problem *s*<sub>1</sub> to a criterion of 15 successive correct responses and then transferred to problem *s*<sub>2</sub> and run to the same criterion. These *S*s made up the "Easy-Hard Transfer Group" called *EH*. The other 11 *S*s were trained first on *s*<sub>2</sub> and then transferred to *s*<sub>1</sub>. This was the "Hard-Easy Transfer Group" called *HE*. The two groups were approximately equated for age, sex, and known special visual skills.

*Results.* Using the pretraining performance of the *EH* group, the average proportion of relevant cues,  $\theta_1$ , was estimated at .254 by equation 8. Using the pretraining performance of the *HE* group, the average proportion of relevant cues in problem *s*<sub>2</sub> was estimated at  $\theta_2 = .138$ .

The transfer performance of group *EH*, which first learned the easy and then the hard problem, is predictable by equation 10. Since these subjects

worked to a high criterion in pretraining, we can assume that  $p(n)$  is negligibly different from one at the end of pretraining. Then by equation 7 we see that  $(1 - \theta_1)^{n-1}$  is small, and equation 10 simplifies to

$$p(n+j) = \frac{\theta_2 + \frac{1}{2}(1 - \theta_2)^{j-1}(\theta_1 - \theta_2)}{\theta_2 + (1 - \theta_2)^{j-1}(\theta_1 - \theta_2)} \quad [12]$$

This theoretical function of *j* is compared with observed transfer performance in Table 4. It is seen that the correspondence is quite close with a negligible constant error.

This prediction is based on the formula which also predicted Lawrence's rat data. This confirmation suggests that the law can be applied to human as well as rat performance on this type of task.

Using the line of reasoning which developed equation 10 we can produce an equation to predict transfer performance from hard to easier problems of the same sort. Certain cues are relevant in the easy problem which were irrelevant in the harder one. These cues cannot be identified in the hard problem. For performance to be perfect in the easier problem all relevant cues must be identified. Therefore, when the subject transfers from the hard to the easier

TABLE 4  
PREDICTION OF TRANSFER OF TRAINING FROM  
EASIER TO HARDER PROBLEM IN  
HUMAN SUBJECTS

Trials after Transfer to Second Problem	Proportion of Correct Responses	
	Observed	Predicted
1-5	.817	.821
6-10	.933	.895
11-15	.926	.941
16-20	.933	.966
21-25	.966	.988
26-30	.983	.994
31-35	1.000	1.000



TABLE 5  
PREDICTION OF TRANSFER OF TRAINING FROM  
HARDER TO EASIER PROBLEM IN  
HUMAN SUBJECTS

Trials After Transfer to Second Problem	Proportion of Correct Responses	
	Observed	Predicted
1-4	.932	.883
5-8	.955	.960
9-12	.955	.984
13-16	1.000	.995

problem we should expect some small number of errors to be made. On the assumption that the hard problem was completely learned in pretraining, the formula for transfer performance on the easy problem is

$$p(n+j) = \frac{\theta_2 + (\theta_1 - \theta_2)(1 - \theta_1)^{j-1}}{\theta_1} \quad [13]$$

where  $\theta_1$  is the proportion of relevant cues in the easy problem and  $\theta_2$  is the proportion of relevant cues in the harder problem. The proof of this theorem is similar to that of equation 12 above, and is not given here.

Equation 13 yields the prediction for transfer performance of the HE subjects. In Table 5 the prediction is compared with observed transfer performance.

Despite the very small frequencies predicted and observed, the prediction is quite accurate. In all, seven errors were made by eleven subjects, whereas a total of eight were expected. This is an average of .64 errors per subject observed, and .73 predicted.

#### DISCUSSION

The definition of a "cue" in terms of possible responses is selected because the theoretical results do not depend critically upon the nature of the stimulating agent. While cues are thought of as stimulus elements,

these elements need not be of the nature of "points of color" or "elementary tones." If a subject can learn a consistent response to a certain configuration despite changes in its constituents, then the configuration is by definition a cue separate from its constituents. The intention is to accept any cue which can be demonstrated to be a possible basis for a differential response.

The process of conditioning described in this paper is formally similar to the processes of conditioning of Estes (5) and Bush and Mosteller (2,3). In the present theory conditioning takes place at each trial, not only on "reinforced" trials. In earlier theories conditioning is said to occur only on such reinforced trials. In two-choice discrimination the incorrect response has a high initial probability (one-half) because of the nature of the physical situation and the way of recording responses. Therefore, a theory of two-choice learning must account for the consistent weakening of such responses through consistent nonreinforcement.

The notion of adaptation used here is formally analogous to the operation of Bush and Mosteller's Discrimination Operator "D" (3). However, whereas Bush and Mosteller's operator is applied only on trials in which the reward condition is reversed for a cue, the present theory indicates that this process takes place each trial. In addition, while the Discrimination Operator and the process of adaptation are both exponential in form, Bush and Mosteller introduce a new exponential constant  $k$  for this purpose and the present theory uses the conditioning constant  $\theta$ .

The major point differentiating the present theory from similar earlier theories is the use of the strong sim-

plifying assumption identifying the exponential constant  $\theta$  with the proportion of relevant cues. This assumption may appear intuitively unlikely, but if it should be shown by further experiment to be tenable, the predictive power of discrimination learning theory is enhanced. There seems to be no reason for abandoning so useful an assumption unless experimental results require it.

#### SUMMARY

A theory of two-choice discrimination learning has been presented. The theory is formally similar to earlier theories of Estes (5) and Bush and Mosteller (3) but differs somewhat in basic concepts and uses a new simplifying assumption.

From this theory three empirical laws are derived: one dealing with the combination of relevant cues, and two dealing with a special type of transfer of training. These laws permitted quantitative predictions of the behavior of four groups of rats and two groups of human subjects. Five of these six predictions were quite accu-

rate, and the sixth was within the range of reasonable sampling deviation.

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## A STIMULUS-RESPONSE ANALYSIS OF THE INTERACTION OF CUE-PRODUCING AND INSTRUMENTAL RESPONSES<sup>1</sup>

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Hull (8), Gibson (6), Dollard and Miller (3), and others (e.g., 1, 2, 5, 13) have been concerned with the role of response-produced stimuli in generalization and discrimination phenomena, verbal rote learning, and other complex behaviors.<sup>2</sup> Of these treatments, Dollard and Miller's mechanisms or paradigms of acquired equivalence and acquired distinctiveness of cues seem to provide the most explicit and general stimulus-response scheme. However, because of their interest in applying these paradigms to social and neurotic behavior, they gave relatively less attention to explicit assimilation of the mechanisms within the network of laboratory-established principles of animal and human learning.

Accordingly, it appears desirable to extend the Dollard and Miller analysis in three directions: (a) to formulate a more general dimensional model—within which acquired equivalence and distinctiveness appear as special cases—of the interaction of external cues, response-produced cues, and instrumental responses; (b) by means of this dimensional model, taken in combination with general principles of response acquisi-

tion and retention, to derive illustrative relationships between the acquisition of cue-producing responses and subsequent learning of instrumental responses; and (c) within the framework of the dimensional scheme and learning principles, to reinterpret a number of special learning and thinking phenomena such as rehearsal, familiarity and meaningfulness of stimuli, and concept formation.<sup>3</sup> The first two of these tasks are essayed in the present paper; the third will be treated in a later publication.

### DIMENSIONAL ANALYSIS

Elements in the mechanisms suggested by Dollard and Miller which provide the basis for a more general dimensional analysis of the functional significance of response-produced stimuli for instrumental behavior are external stimuli, cue-producing responses and resultant cues, and emotional or instrumental responses. In line with these authors, cue-producing responses will be defined functionally rather than topographically (3, p. 99). Verbal mediating responses and emotional or nonverbal instrumental responses were of greatest concern to Dollard and Miller and will be emphasized in the present context. However, manipulative and other nonverbal responses (1, 10) can presumably function as mediating processes in both human and infrahuman behavior.

<sup>1</sup> R. M. Gagné, I. L. (Rossman) Gerjuoy, R. B. Houton, and N. E. Miller (personal communications) have contributed suggestions which, while not specifically acknowledged, have been most useful. In addition, the author is greatly indebted to M. E. W. Goss, W. E. Jeffrey, D. S. Palermo, and B. J. Underwood for critical readings of parts or all of various versions of the manuscript.

<sup>2</sup> Since this article is not intended as an exhaustive survey of relevant literature, only selected studies and theoretical papers have been noted. Other pertinent materials have been noted in (1, 7, 11, 12, 17).

<sup>3</sup> A dimensional model is here considered as the outcome of an analysis of particular behavioral phenomena into stimulus and response variables and possible interrelationships among those dimensions.

### Dollard and Miller's Mechanisms

Dollard and Miller have defined or specified the functional properties of acquired equivalence and acquired distinctiveness as follows:

*Acquired equivalence.* "Attaching the same cue-producing response to two distinctive stimulus objects gives them a certain learned equivalence increasing the extent to which instrumental and emotional responses will generalize from one to the other" (3, p. 101).

*Acquired distinctiveness.* "Attaching distinctive cue-producing responses to similar stimulus objects tends to increase their distinctiveness" (3, pp. 101-102).

These mechanisms have been diagrammed in Fig. 1 by the use of bright ( $S_B$ ), medium ( $S_M$ ), and dim ( $S_D$ ) in-

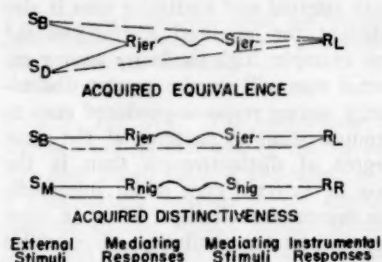


FIG. 1. Acquired-equivalence and acquired-distinctiveness relationships as postulated by Dollard and Miller.

tensities of light from a single source as external stimuli, two verbal responses ( $R_{jer}$ ,  $R_{nig}$ ) each producing cues ( $S_{jer}$ ,  $S_{nig}$ ), and two instrumental responses of moving a lever attached to a universal joint to the right ( $R_R$ ) or left ( $R_L$ ).<sup>4</sup> The solid lines of the top diagram represent an acquired-equivalence condition involving two physically dissimilar lights,  $S_B$  and  $S_D$ , each of which

evokes the sequence  $R_{jer} \sim S_{jer}$ . Because of the common verbal cue,  $S_{jer}$ , the resultant stimulus patterns,  $S_B + S_{jer}$  and  $S_D + S_{jer}$ , are assumed to be more similar to each other than  $S_B$  and  $S_D$  alone. Therefore, as indicated by the dashed lines, conditioning  $S_B + S_{jer}$  to  $R_L$  should result in greater probability that  $S_D$ , through the presence of  $S_{jer}$  in the pattern  $S_D + S_{jer}$ , would evoke  $R_L$ , than would have been the case had  $S_B$  alone been conditioned to  $R_L$  with a subsequent test for generalization of  $R_L$  to  $S_D$ .

An acquired-distinctiveness relationship is depicted in the bottom diagram. Two similar stimuli,  $S_B$  and  $S_M$ , lead to different and dissimilar response-produced cues,  $S_{jer}$  and  $S_{nig}$ , respectively. It is assumed that the resultant stimulus patterns,  $S_B + S_{jer}$  and  $S_M + S_{nig}$ , are more dissimilar than  $S_B$  and  $S_M$  alone. Accordingly, less generalization of  $R_L$  from  $S_B + S_{jer}$  to  $S_M + S_{nig}$  and of  $R_R$  from  $S_M + S_{nig}$  to  $S_B + S_{jer}$  would be anticipated than under the condition of  $S_B$  and  $S_M$  alone as differential cues for the two instrumental responses. Also, because of greater distinctiveness, more rapid acquisition of  $S_B + S_{jer} \rightarrow R_L$  and  $S_M + S_{nig} \rightarrow R_R$  (broken lines) is predicted than of  $S_B \rightarrow R_L$  and  $S_M \rightarrow R_R$ .

### The Dimensional Model

Expansion of the number of stimulus-response components and more explicit consideration of degree of similarity of external and mediating cues will here constitute the initial steps in the development of a more general model. The role of response probability will then be considered. After acquired equivalence and acquired distinctiveness have been redefined within the expanded model and other relationships suggested, the final step of the dimensional expansion will be the assimila-

<sup>4</sup> The prototypes of Fig. 1 and subsequent diagrams were originated by Birge (1) and further developed by Thompson (17). In this article, the pairs of terms, cue-producing response and mediating response, and response-produced cues (stimuli) and mediating cues (stimuli), are used interchangeably.

tion or representation within the model of additional variables and relationships.

### Expansion

**Number of components.** In Fig. 2 the number of stimulus-response components has been increased from three to four different intensities of white light (very bright,  $S_{VB}$ ; bright,  $S_B$ ; dim,  $S_D$ ; and very dim,  $S_{VD}$ ) and from two to four nonsense syllable responses ( $R_{jer}$ ,  $R_{ner}$ ,  $R_{neg}$ ,  $R_{nig}$ ) of differing formal similarity each producing corresponding cues ( $S_{jer}$ ,  $S_{ner}$ ,  $S_{neg}$ ,  $S_{nig}$ ). Acquired equivalence is represented in the top diagram if it is assumed that the patterns  $S_{VB} + S_{jer}$ ,  $S_B + S_{jer}$ ,  $S_D + S_{jer}$ ,  $S_{VD} + S_{jer}$ ,  $S_{VB} + S_{jer}$ , which result from

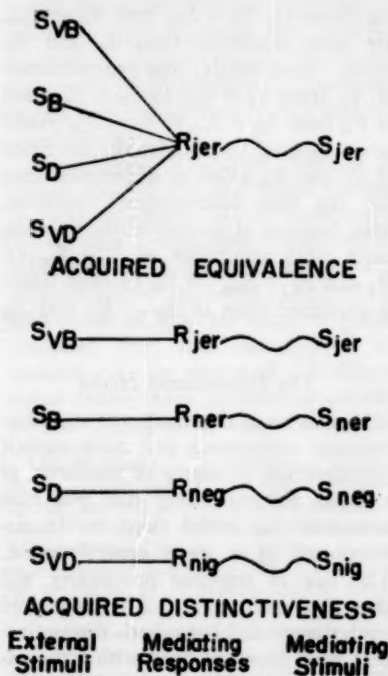


FIG. 2. Expansion of stimulus-response components of acquired-equivalence and acquired-distinctiveness paradigms.

the evocation of  $R_{jer}$  by each of the four external stimuli, are more similar than the four lights alone. In the bottom diagram, the stimulus patterns  $S_{VB} + S_{jer}$ ,  $S_B + S_{jer}$ ,  $S_D + S_{jer}$ ,  $S_{VD} + S_{jer}$  are conceived as less similar than the four intensities alone. Thus, the addition of mediating cues presumably provides acquired distinctiveness or dissimilarity among the more similar external cues.

With respect to acquired equivalence, greater similarity of the external cues should decrease the contribution of the common mediating component of the stimulus pattern, while less similarity of these cues should increase this contribution. The degree of similarity of both external and mediating cues is also relevant for acquired distinctiveness.<sup>8</sup> For example, high similarity among external cues will require greater dissimilarity among response-produced cues to produce stimulus patterns of the same degree of distinctiveness than in the case of external cues of an intermediate degree of similarity. Thus, in more general terms, similarity of stimulus patterns must be specified as some joint product of degree of similarity among sets of external and mediating cues.

Other combinations of external and mediating cues can be formed. Thus  $S_{VB}$  and  $S_B$  might both evoke  $R_{jer}$  while  $R_{nig}$  is elicited by

<sup>8</sup> Similarity can be expressed in physical terms as extent of differences along physical dimensions. Differences in numbers of common elements can also be used. Psychophysical definitions of similarity are functions of such differences, the experimenter's instructions, and subjects' responses. Also, although possibly subsumed under the instructions factor, mediating stimuli probably play a role in such determinations. For the analytical purpose of the present paper, however, it is assumed that the relative similarity of external and of mediating cues can, in principle, be specified separately with a minimum of involvement of other mediating cues.



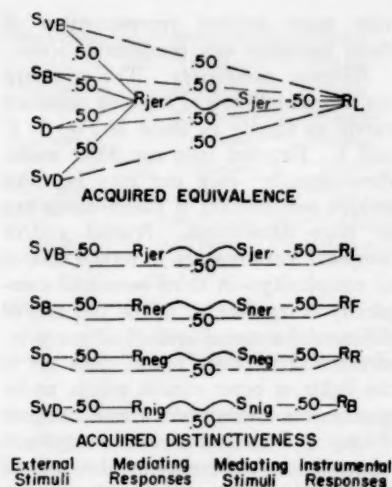


FIG. 3. Acquired equivalence and acquired distinctiveness including response probabilities and instrumental responses.

both  $S_D$  and  $S_{VD}$ . The equivalence of the  $S_{VB}$  and  $S_B$  pair and of the  $S_D$  and  $S_{VD}$  pair would then be increased, with a concomitant increase in the distinctiveness of the stimuli of the former pair with respect to those of the latter pair.

**Instrumental responses and response probabilities.** Movements of a lever to the left ( $R_L$ ), forward ( $R_F$ ), right ( $R_R$ ), or backward ( $R_B$ ) have been introduced as instrumental responses (Fig. 3). Also, assumed probabilities that external or mediating stimuli will evoke the responses have been added. These probabilities have been specified by the numbers in the breaks of the lines which connect various stimuli and responses. Specific assumptions concerning the probabilities that stimuli will evoke responses are: (a) the probability that a given stimulus will evoke a response varies from .00 to 1.00 (where no lines connect stimuli and responses, the probability of response occurrence to those stimuli is taken as .00); (b)

external and/or mediating stimuli can elicit one, two, or more mediating or instrumental responses subject to the restriction that the separate probabilities summate to a maximum of 1.00; and (c) the sets of probabilities that external cues will arouse two or more mediating and/or instrumental responses are independent of the probabilities that response-produced cues will elicit one or more instrumental responses. For expository purposes these probabilities are taken as resultant probabilities. That is, they are considered the outcome of the absolute and relative strengths of the habits for competing responses (8) or of trial-by-trial variations in samples of elements (4). It is also assumed that each mediating response will evoke only one mediating stimulus, this sequence being given a probability of 1.00.

The incorporation of response probabilities within the model will ultimately require more specific consideration of procedures for combining separate probabilities that external and mediating cues elicit instrumental responses.<sup>6</sup> With probabilities that external cues evoke instrumental responses held constant, however, the probabilities of occurrence of instrumental responses will be products of the separate probabilities of external cues arousing mediating stimuli and of mediating stimuli evoking instrumental responses.

Furthermore, acquired equivalence and acquired distinctiveness must now be treated in probability terms. Because of the assumed probabilities of .50 for associations between external cues and mediating responses in the diagrams of Fig. 3, acquired equivalence

<sup>6</sup> Hull's (8) procedure for habit summation represents one attempt to deal with this general problem. Or, the problem might reduce to a solution such as a larger "N" within Estes and Burke's (4) statistical conception of learning.

lence or acquired distinctiveness will operate on only one-half of the occurrences of external stimuli. Of course, the probabilities of .50 that external and mediating stimuli elicit instrumental responses introduce additional contingencies.

Any values from .00 to 1.00 could have been substituted in Fig. 3 for the illustrative probabilities of .50. With stimulus-response associations thus conceived, acquired equivalence and acquired distinctiveness appear as special cases or extremes of phenomena existing in degree. Moreover, in order for either mechanism to play a significant role in the acquisition and evocation of instrumental responses, the probabilities that given external stimuli will arouse cue-producing responses should approach 1.00.

Recognition should also be given to the possibility that low probabilities for cue-producing responses of acquired equivalence or distinctiveness and high probabilities of occurrences of other verbal responses might retard the acquisition of discriminative or generalized instrumental responses. In the acquired equivalence diagram of Fig. 3, for example, the arousal of  $R_{neg}$  by  $S_{VD}$  instead of  $R_{jer}$  should decrease generalization of  $R_L$  from  $S_{VD}$  to  $S_D$ . Or, in the bottom diagram, because of the similarity of  $S_{neg}$  and  $S_{sig}$ , arousal of  $R_{neg}$  by  $S_{VD}$  might increase the similarity of  $S_{VD}$  and  $S_D$  and thus slow down the acquisition of the discriminative instrumental responses,  $R_R$  and  $R_B$ , to  $S_D$  and  $S_{VD}$ , respectively.

#### *Additional Variables and Relationships*

The significance of stimulus complexity, relationships among cue-producing responses, and "warm-up" phenomena for acquired equivalence and distinctiveness has received little attention. As a consequence, the steps which follow are preliminary efforts to pro-

vide more explicit representation of these variables and conditions.

*Stimulus complexity.* The stimulus-response conditions of learning tasks are rarely as simple as those in Fig. 1, 2, and 3. External cues can differ multidimensionally; each one may be some unique combination of values along two or more dimensions. Spatial and/or temporal patterns are a second source of complexity. A third source of complexity is represented in the two sets of differential external stimuli of many instrumental response tasks. One set is the lights or other stimuli which, under appropriate instructions, arouse cue-producing and/or instrumental responses. Many motor tasks also involve sets of levers, knobs, buttons, etc. whose selection and manipulation constitute instrumental responses. Thus, each of the actual differential cues of many instrumental tasks might be considered a two-component pattern made up of one of the manipulanda for the instrumental responses and a paired, spatially separated "signalling" cue such as one of the lights.<sup>7</sup>

These variations, alone or in combination, raise the possibility that each complex external cue of verbal or motor tasks will elicit several verbal responses. Some verbal responses of varying probabilities of occurrence will probably be unique to a given complex cue, while others might be aroused by two or more of the complex cues.

Figure 4 schematizes relationships which might be obtained for stimulus complexity based on multidimensional variation. The external stimuli are diagrammed as differing with respect to intensity, wave length, and simple form. Probabilities with which each stimulus arouses verbal responses for differences

<sup>7</sup> If receptor-orienting responses (16, 18) must be learned to assure differential stimulation, an additional set of response-produced cues is introduced.

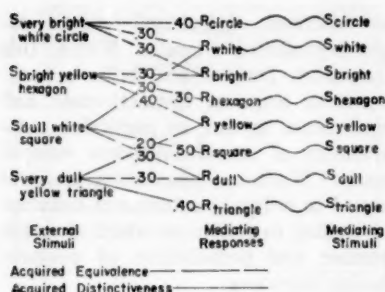


FIG. 4. Acquired-equivalence and acquired-distinctiveness relationships for complex stimuli.

along each of these dimensions have also been introduced. High probabilities for form responses ( $R_{circle}$ ,  $R_{hexagon}$ , etc.) would provide acquired distinctiveness. On the other hand, if the two bright and the two dull, or the two white and the two yellow, evoked their common responses with high probabilities, some degree of acquired equivalence would obtain. Because of the low response probabilities which have been assumed, however, neither mechanism would be consistently operative.

Complexity of mediating cues must also be recognized. Verbal mediating cues can differ multidimensionally with respect to duration and amplitude. Or, such cues might be single letters or numbers or increasingly complex combinations of such elements as nonsense syllables, words, or identifying numbers. Furthermore, response-produced cues can presumably elicit other cue-producing responses. Therefore, varying degrees of complexity might arise from patterns of cues produced by sequences of cue-producing responses.

**Relationships between mediating responses.** Associations between response-produced cues and cue-producing responses might have other effects. Thus, in Fig. 3 if  $S_{nig}$  came to elicit  $R_{neg}$ , the acquired distinctiveness of  $S_{VD}$  and  $S_D$  would be reduced. Although not dia-

grammed in Fig. 3, occurrences of parallel sequences of different cue-producing responses such as  $S_{VD}$  leading to  $R_{nig} \sim S_{nig} \sim R_{sil} \sim S_{sil} \sim R_{nok} \sim S_{nok}$  and  $S_D$  arousing  $R_{neg} \sim S_{neg} \sim R_{guz} \sim S_{guz} \sim R_{das} \sim S_{das}$ , by adding further distinctive response-produced cues to the stimulus patterns, should produce greater dissimilarity. Also possible are situations in which dissimilar external cues elicit sequences of verbal responses that produce increasingly similar verbal stimuli and thereby enhance equivalence. Other relationships between cue-producing responses have been treated in detail by Cofer and Foley (2).

**Warm-up, etc.** It has been observed that pretask experiences which are relatively nonspecific to the stimulus-response relationships of the tasks sometimes influence subsequent acquisition or retention of such relationships. The apparent effects of these pretask or warm-up experiences have been explained by hypothesizing *learning-how-to-learn* and *learning set* processes. In turn, these hypothesized processes have been reduced to postural adjustments, receptor-orienting and exposure responses, etc. (9).

To the degree that pretask experiences lead to the development of postural adjustments, and to receptor-orienting and exposure responses, the proportions of learning or retention trials on which external stimuli are "paid attention to" or received and/or the duration of reception on each trial should increase. The more frequent and longer the reception of stimuli the greater the number of cue-producing responses which would be elicited on each trial. Furthermore, higher probabilities of the occurrence of a given response on a single trial as well as increments in the number of mediating cue and cue-producing response rela-

tionships would be anticipated. Thus, warm-up could be conceptualized within the dimensional model as increased numbers and probabilities of occurrence of cue-producing responses on each trial. In addition, for some tasks the acquisition of receptor-orienting responses would heighten the probability that critical differential cues would be received. Such responses would have the effect of increasing the dissimilarity of external cues (16, 18). Under some conditions, however, enhanced similarity might result.

The number and probabilities of occurrence of cue-producing responses might also be altered by experiences which are more specific to the external stimuli. For example, it has been observed that experiences in seeing or seeing and discriminating stimuli influence subsequent discriminative motor learning (7). The strengthening of responses of looking for the specific parts or part-characteristics which differentiate complex stimuli might also be relevant (14). Finally, experiences or instructions which alter the probabilities of occurrence of responses to the dimensions along which sets of external stimuli are the same or different should be considered.

#### *Summary of Dimensional Scheme*

The interactions of cue-producing and instrumental responses in complex behaviors can be dimensionalized in terms of the *number, similarity, probabilities of occurrence, and complexity* of the following factors: (a) external stimulus events, (b) cue-producing responses and response-produced cues occurring in the presence of given external stimuli, (c) cue-producing responses and resultant cues arising in relation to response-produced stimuli alone or in combination with other response-produced stimuli and/or external cues, and (d) instrumental or emotional responses

as functions of external and/or response-produced stimuli. Within this framework Dollard and Miller's paradigms of acquired distinctiveness and equivalence appear as particular combinations of stimulus-response components. Warm-up experiences are presumed to influence subsequent behavior by leading to conditions which alter the number and probabilities of cue-producing responses.

#### **DIMENSIONAL ANALYSIS AND LEARNING PRINCIPLES**

The presence of acquired distinctiveness, acquired equivalence, or other verbal-motor response relationships depends on particular combinations of probabilities of occurrence of cue-producing and/or instrumental responses. These combinations can be expected to vary as functions of classes of conventional learning variables (e.g., parameters of reinforcement of component stimulus-response units). Therefore, the usefulness of the dimensional scheme, when supplemented by general learning principles (13), will be illustrated by presenting quasi-quantitative, semiformal derivations of relationships between the conditions under which cue-producing responses are acquired and subsequent learning of instrumental responses. Specifically, model derivations will be outlined for direction and amount of transfer to discriminative motor learning as a function of number of discriminative verbal learning trials, and as influenced by the similarity of external cues common to both verbal and motor tasks. Possible relationships between motor learning and selected additional variables will then be noted without, however, detailed development of specific hypotheses.

#### *Model Derivations*

*Number of verbal learning trials.* On the assumption that dissimilar verbal

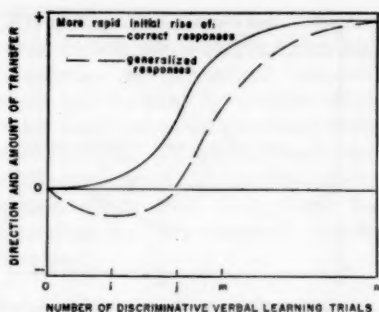


FIG. 5. Predicted general forms of the relationship between direction and amount of transfer and number of verbal learning trials.

responses to similar external stimuli increase differences in stimulus patterns, increased probabilities of verbal responses should occasion variation in the rate of learning of discriminative instrumental responses to the same stimuli. In order to specify direction and amount of transfer, however, possible effects of generalized responses must be considered. Because of primary stimulus generalization, each external cue will elicit not only its paired ("correct," dissimilar, or discriminative) response but also generalized responses (errors of generalization, "confusions," intralist intrusions). Enhanced similarity arising from acquired equivalence attributable to generalized responses will tend to offset increased dissimilarity of external and verbal cue patterns based on the acquisition of dissimilar labels.

Gibson (6) has hypothesized that while frequency of correct responses increases monotonically as a function of trials, the curve for generalized responses increases to a maximum and then decreases. If both generalized and correct responses increase initially, however, the interfering effects of the generalized responses should preclude marked positive transfer to discriminative motor tasks until sufficient trials have been given for these responses to

begin to decline in frequency. If generalized responses increase more rapidly than correct responses, small numbers of verbal learning trials might lead to some negative transfer. Relative rates of rise of correct and generalized responses (and, by implication, the forms of transfer curves) are considered functions of degree of similarity of external cues. It has been assumed that the curves of Fig. 5 approximate those which might be obtained with external stimuli of an intermediate degree of similarity. Contingent on the relative rates of increase of correct and generalized responses, hypothesized directions and amounts of transfer to discriminative motor learning have been plotted as functions of number of discriminative verbal learning trials. A more rapid initial rise of correct responses should result in the solid-line relationship. The broken-line curve might be obtained with steeper initial increases in generalized responses.

Although consistent with the notion of a slow initial rise, neither the Gagné and Baker (5) nor the Rossman and Goss (14) findings are based on sufficient points to decide between these alternative curves. Because only high

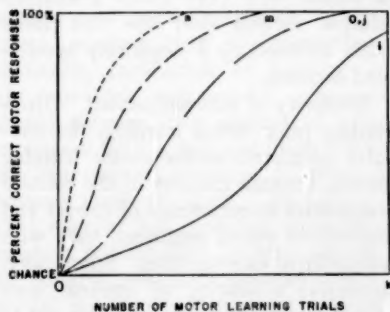


FIG. 6. Predicted family of curves for percentages of correct motor choices as a function of number of motor learning trials with amount of prior verbal training as the parameter.



levels of verbal response strength or one degree of verbal learning was employed, the results of other studies cannot be used for such a decision.

Proceeding on the basis of the broken-line or negative-transfer curve, number of verbal learning trials was used to generate a hypothetical family of curves relating percentages of correct motor discriminations to number of motor learning trials (Fig. 6). The slow initial rises for the curves with  $i$ , 0,  $j$ , and  $m$  discriminative verbal learning trials as parameters also stem from the assumption that generalized responses interfere with facilitation attributable to different verbal responses to each stimulus. Thus the greater the number of generalized responses, the greater and more prolonged the interference with acquisition of motor discriminations. Rossman and Goss (14) and Smith and Goss (15) obtained curves with slow initial rises in correct motor discrimination measures. While Gagné and Baker's (5) curves for response times are negatively accelerated, the plots of errors for the 0-, 8-, and 16-trial verbal learning conditions could be the initial segments of S-shaped curves. The curve for correct responses of McAllister's (11) group 2 exhibits relative flatness over the first three trials followed by a negatively accelerated increase.

*Similarity of external stimuli.* Disregarding prior verbal learning, the difficulty of discriminative motor learning should, through changes in the relative frequencies of occurrence of correct and generalized verbal responses, vary with similarity of external cues. Specifically, increasing similarity of external cues should lead to lower rates of rise and to lower final asymptotes for correct verbal response curves. Generalized verbal responses would be expected to rise more rapidly to higher levels and then to de-

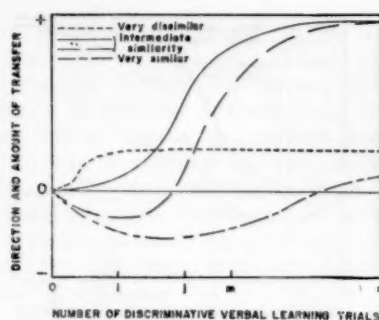


FIG. 7. Predicted family of curves for direction and amount of transfer to a motor task as a function of the number of discriminative verbal learning trials with similarity of stimuli as the parameter.

crease from the maxima less rapidly as a function of increasing similarity.

Figure 7 represents hypothesized relationships between transfer and number of verbal learning trials for sets of external stimuli which are assumed to be very dissimilar, of an intermediate degree of similarity, or very similar. Although plotted against the same zero (0) transfer line, a different control group would be necessary for each degree of similarity. Negligible occurrence and strengthening of mediating responses during the course of instrumental learning have been assumed. Because dissimilarity of external cues should result in relatively infrequent generalized verbal responses, it is probable, as suggested by the dotted-line curve, that only facilitation with little or no positive acceleration would be observed. The solid- and broken-line curves which duplicate those of Fig. 5 are alternative representations of transfer as a function of verbal learning experiences with stimuli of some intermediate degree of similarity.

Very similar external stimuli should occasion a rapid initial rise in generalized responses to a high level and a relatively small and slow subsequent

decrement. Therefore, the remaining curve depicts the possibility that high frequencies of generalized responses might lead to negative transfer effects which would persist despite many verbal learning trials. Moreover, the relatively small decrements in generalized responses might lead to a fairly low asymptote for any eventual positive transfer.

#### *Relationships Involving Other Variables*

Neither space nor available data justify the continuation of relatively explicit and complete derivations on a variable-by-variable basis. It would seem desirable, however, to illustrate further the range of relationships between acquisition of cue-producing and instrumental responses which can be developed by means of the dimensional model and learning principles. Therefore, relationships involving four arbitrarily selected variables or conditions of learning prior to acquisition of instrumental responses to external cues will be treated. These variables or conditions are: (a) similarity of response-produced cues, (b) inhibition of cue-producing responses, (c) relationships between response-produced cues and instrumental responses, and (d) changes in the similarity of the external stimuli of the tasks of first learning cue-producing responses and then acquiring instrumental responses.

*Similarity of verbal response-produced cues.* Because similarity of cue patterns was conceived as determined by similarity of both external and mediating stimuli, changes in similarity of the latter cues should influence acquisition of instrumental responses. For example, with dissimilar external cues held constant it would be predicted that an increase in the similarity of response-produced cues would shift the hypothesized relationship between transfer and

number of discriminative verbal learning trials from the dotted-line curve of Fig. 7 toward the alternative forms for external cues of intermediate similarity. Eventually, the curve for very similar external cues might be approximated.

*Inhibition of cue-producing responses.* Rossman and Goss (14) and Murdock (12) have reported that conditions (electric shock, failure, acquisition of competing responses) intervening between verbal and motor learning which lead to inhibition of verbal responses may decrease both discriminative motor learning and generalization of instrumental responses. Accordingly, it appears likely that instrumental-response learning will be influenced by conditions which inhibit cue-producing responses. The specific consequences of such inhibition will, of course, depend on the functional role of the cue-producing responses in the learning of instrumental responses.

*Relationships between response-produced cues and instrumental responses.* Direction and amount of transfer to motor learning tasks should vary with conditions of acquisition and resultant strengths of associations of mediating cues and instrumental responses. Thus, given dissimilar verbal responses, each elicited with high probability by different external cues of intermediate similarity, facilitation of learning of discriminative instrumental responses should increase with amount of prior experience with a task requiring different instrumental responses to different response-produced cues. McAllister's (11) *relevant* S-R condition apparently assumes relationships between mediating stimuli and discriminative instrumental responses. If types of *relevant* S-R relationships are interpreted as also involving different degrees of strength of mediating cue-instrumental response relationships, her results are consistent with this notion.

*Similarity of external stimuli of cue-producing-response and instrumental-response learning.* The relationships treated up to this point rest on the condition that the same external stimuli, mediating responses and stimuli, and instrumental responses are present during the strengthening of associations between these components. However, intertask changes in similarity and/or number of any one or any combination of stimulus-response elements could be expected to affect the acquisition of discriminative instrumental responses. Discriminative verbal response to external stimuli of high or intermediate similarity may have been learned to a high level of mastery. As similarity between those stimuli and external cues for a subsequent discriminative motor task decreases, a monotonic decrease in dissimilar verbal responses to each external cue and an increase and subsequent decrease in generalized responses should be observed. Therefore, amount of positive transfer should decrease and, contingent on changes in the relative frequencies of discriminative and generalized responses, some negative transfer might be obtained before reaching a zero transfer point.

#### SUMMARY

Dollard and Miller's mechanisms of the acquired equivalence and acquired distinctiveness of cues served as bases for a more general dimensional analysis of the interaction of cue-producing and instrumental responses. With external cues, cue-producing responses and resultant cues, and instrumental responses as stimulus-response components, the model provided for the effects of response probabilities, stimulus complexity, relationships between cue-producing responses, and conditions such as warm-up.

The dimensional model and general

principles of response acquisition and retention were linked by means of response probabilities. It was then possible to outline model derivations of the influence of number of discriminative verbal learning trials and of similarity of external cues on rate of acquisition of discriminative instrumental responses. Brief attention was also given to the learning of instrumental responses as a function of: (a) similarity of response-produced cues, (b) inhibition of cue-producing responses, (c) relationships between response-produced cues and instrumental responses, and (d) similarity of external cues for cue-producing and subsequent instrumental responses.

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## PERCEPTUAL LEARNING: DIFFERENTIATION OR ENRICHMENT?<sup>1</sup>

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The term "perceptual learning" means different things to different psychologists. To some it implies that human perception is, in large part, learned—that we learn to see depth, for instance, or form, or meaningful objects. In that case the theoretical issue involved is *how much* of perception is learned, and the corresponding controversy is that of nativism or empiricism. To others the term implies that human learning is in whole or part a matter of perception—that learning depends on comprehension, expectation, or insight, and that the learning process is to be found in a central process of cognition rather than in a motor process of performance. In this second case, the theoretical issue involved is whether or not one has to study a man's perceptions before one can understand his behavior, and the controversy is one of long standing which began with old-fashioned behaviorism.

These two sets of implications are by no means the same, and the two problems should be separated. The problem of the role of learning in perception has to do with perception and the effect of past experience or practice on it. The problem of the role of perception in learning has to do with behavior and the question of whether we can learn to do something by perceiving, or whether we can only learn by doing it. The questions, then, are these: (a) In

what sense do we learn to perceive? (b) In what sense can we learn by perceiving? Both questions are important for the practical problems of education and training, but this paper will be concerned with the former.

### IN WHAT SENSE DO WE LEARN TO PERCEIVE?

This question has roots in philosophy and was debated long before experimental psychology came of age. Does all knowledge (information is the contemporary term) come through the sense organs or is some knowledge contributed by the mind itself? Inasmuch as sensory psychology has been unable to explain how as much information about the world as we manifestly do obtain is transmitted by the receptors, some theory is required for this unexplained surplus. There has been a variety of such theories ever since the days of John Locke. An early notion was that the surplus is contributed by the rational faculty (rationalism). Another was that it comes from innate ideas (nativism). In modern times there have been few adherents to these positions. The most popular theory over the years has been that this supplement to the sensations is the result of learning, and that it comes from past experience. A contemporary formula for this explanation is that the brain stores information—possibly in the form of traces or memory images, but conceivably as attitudes, or mental sets, or general ideas, or concepts. This approach has been called empiricism. It preserves the dictum that all knowledge comes from experience by assum-

<sup>1</sup> This paper is a revision, with added experimental material, of one given in May 1953 at a symposium on the psychology of learning basic to problems of military training (8) conducted by the Panel on Training and Training Devices of the Research and Development Board, Washington, D. C.



ing that past experience somehow gets *mixed with* present experience. It assumes, in other words, that experience *accumulates*, that traces of the past somehow exist in our perception of the present. One of its high-water marks was Helmholtz's theory of unconscious inference, which supposes that we learn to see depth by interpreting the clues furnished by the depthless sensations of color. Another was Titchener's context theory of meaning, which asserts that we learn to perceive objects when a core of sensations acquires by association a context of memory images.

Over a generation ago this whole line of thought was challenged by what seemed to be a different explanation for the discrepancy between the sensory input and the finished percept—the theory of sensory organization. The gestalt theorists made destructive criticisms of the notion of *acquired* linkages among sensory elements and their traces. Instead they asserted that the linkages were *intrinsic*, or that they arose *spontaneously*, taking visual forms as their best example. Perception and knowledge, they said, were or came to be *structured*.

The theory of sensory organization or cognitive structure, although it generated a quantity of experimentation along new lines, has not after 30 years overthrown the theory of association. In this country the old line of empiricist thinking has begun to recover from the critical attack, and there are signs of a revival. Brunswik (2, pp. 23 ff.) has followed from the start the line laid down by Helmholtz. Ames and Cantril and their followers have announced what might be called a neoempiricist revelation (3, 11, 14). Other psychologists are striving for a theoretical synthesis which will include the lessons of gestalt theory but retain the notion that perception is learned. Tolman, Bartlett, and Woodworth began the trend.

Leeper took a hand in it at an early date (15). The effort to reconcile the principle of sensory organization with the principle of determination by past experience has recently been strenuously pursued by Bruner (1) and by Postman (16). Hilgard seems to accept both a process of organization governed by relational structure and a process of association governed by the classical laws (10). Hebb has recently made a systematic full-scale attempt to combine the best of gestalt theory and of learning theory at the physiological level (9). What all these theorists seem to us to be saying is that the organization process and the learning process are not inconsistent after all, that both explanations are valid in their way, and that there is no value in continuing the old argument over whether learning is really organization or organization is really learning. The experiments on this issue (beginning with the Gottschaldt experiment) were inconclusive, and the controversy itself was inconclusive. Hence, they argue, the best solution is to agree with both sides.

It seems to us that all extant theories of the perceptual process, including those based on association, those based on organization, and those based on a mixture of the two (including attitudes, habits, assumptions, hypotheses, expectation, images, contexts, or inferences) have at least this feature in common: they take for granted a discrepancy between the sensory input and the finished percept and they aim to explain the difference. They assume that somehow we get more information about the environment than can be transmitted through the receptor system. In other words, they accept the distinction between sensation and perception. The development of perception must then necessarily be one of supplementing or interpreting or organizing.

Let us consider the possibility of rejecting this assumption altogether. Let us assume tentatively that the stimulus input contains within it everything that the percept has. What if the flux of stimulation at receptors *does* yield all the information anyone needs about the environment? Perhaps all knowledge comes through the senses in an even simpler way than John Locke was able to conceive—by way of variations, shadings, and subtleties of energy which are properly to be called stimuli.

#### THE ENRICHMENT THEORY VERSUS THE SPECIFICITY THEORY

The entertaining of this hypothesis faces us with two theories of perceptual learning which are clear rather than vague alternatives. It cuts across the schools and theories, and presents us with an issue. Is perception a creative process or is it a discriminative process? Is learning a matter of enriching previously meagre sensations or is it a matter of differentiating previously vague impressions? On the first alternative we might learn to perceive in this sense: that percepts change over time by acquiring progressively more memory images, and that a context of memories accrues by association to a sensory core. The theorist can substitute attitudes or inferences or assumptions for images in the above Titchenerian proposition, but perhaps all this does is to make the theory less neat while making the terminology more fashionable. In any case perception is progressively in *decreasing correspondence with stimulation*. The latter point is notable. Perceptual learning, thus conceived, necessarily consists of experience becoming more imaginary, more assumptive, or more inferential. The dependence of perception on learning seems to be contradictory to the principle of the dependence of perception on stimulation.

On the second alternative we learn to perceive in this sense: that percepts change over time by progressive elaboration of qualities, features, and dimensions of variation; that perceptual experience even at the outset consists of a world, not of sensation, and that the world gets more and more properties as the objects in it get more distinctive; finally, that the phenomenal properties and the phenomenal objects correspond to physical properties and physical objects in the environment *whenever learning is successful*. In this theory perception gets richer in differential responses, not in images. It is progressively in *greater* correspondence with stimulation, not in less. Instead of becoming more imaginary it becomes more discriminating. Perceptual learning, then, consists of responding to variables of physical stimulation not previously responded to. The notable point about this theory is that learning is always supposed to be a matter of improvement—of getting in closer touch with the environment. It consequently does not account for hallucination or delusions or, in fact, for any kind of maladjustment.

The latter kind of theory is certainly worth exploring. It is not novel, of course, to suggest that perceptual development is a matter of differentiation. As phenomenal description this was asserted by some of the gestalt psychologists, notably Koffka and Lewin. (Just how differentiation was related to organization, however, was not clear.) What is novel is to suggest that perceptual development is always a matter of the correspondence between stimulation and perception—that it is strictly governed by the relationships of the perceiver to his environment. The rule would be that, as the number of distinct percepts a man can have increases, so also the number of different physical objects to which they are specific in-

creases. An example may clarify this rule. One man, let us say, can identify sherry, champagne, white wine, and red wine. He has four percepts in response to the total possible range of stimulation. Another man can identify a dozen types of sherry, each with many varieties, and numerous blends, and so on for the others. He has four thousand percepts in response to the range of stimulation. The crucial question to ask about this example of differentiated perception is its relation to stimulation.

Stimulus is a slippery term in psychology. Properly speaking stimulation is always energy at receptors, that is, proximal stimulation. An individual is surrounded by an array of energy and immersed in a flow of it. This sea of stimulation consists of variation and invariants, patterns and transformations, some of which we know how to isolate and control and others of which we do not. An experimenter chooses or constructs a sample of this energy when he performs a psychological experiment. But it is easy for him to forget this fact and to assume that a glass of wine is a stimulus when actually it is a complex of radiant and chemical energies which is the stimulus. When the psychologist refers to stimuli as cues, or clues, or carriers of information he is skipping lightly over the problem of how stimuli come to *function* as cues. Energies do not have cue properties unless and until the differences in energy have correspondingly different effects in perception. The total range of physical stimulation is very rich in complex variables and these are theoretically capable of becoming cues and constituting information. This is just where learning comes in.

All responses to stimulation, including perceptual responses, manifest some degree of specificity, and, inversely, some degree of nonspecificity. The gentleman who is discriminating about

his wine shows a high specificity of perception, whereas the crude fellow who is not shows a low specificity. A whole class of chemically different fluids is equivalent for the latter individual; he can't tell the difference between claret, burgundy, and chianti; his perceptions are relatively undifferentiated. What has the first man learned that the second man has not? Associations? Memories? Attitudes? Inferences? Has he learned to have perceptions instead of merely sensations? Perhaps, but a simpler statement might be made. The statement is that he has learned to taste and smell more of the qualities of wine, that is, he discriminates more of the variables of chemical stimulation. If he is a genuine connoisseur and not a fake, one combination of such variables can evoke a specific response of naming or identifying and another combination can evoke a different specific response. He can consistently apply nouns to the different fluids of a class and he can apply adjectives to the differences between the fluids.

The classical theory of perceptual learning, with its emphasis on subjective determination of perception in contrast to stimulus determination, gets its plausibility from experiments on errors in form perception, from the study of illusions and systematic distortions, and from the fact of individual differences in and social influences on perception. The learning process is assumed to have occurred in the past life of the experimental subject; it is seldom controlled by the experimenter. These are *not* learning experiments insofar as they do not control practice or take measures before and after training. True perceptual learning experiments are limited to those concerned with discrimination.

One source of evidence about discriminative learning comes from the study of the cues for verbal learning.

The analysis of these cues made by one of the authors in terms of stimulus generalization and differentiation (4) suggests the present line of thought. It has also led to a series of experiments concerned with what we call *identifying responses*. Motor reactions, verbal reactions, or percepts, we assume, are identifying responses if they are in specific correspondence with a set of objects or events. Code learning (13), aircraft recognition (7), and learning to name the faces of one's friends are all examples of an increasingly specific correspondence between the items of stimulation presented and the items of response recorded. As a given response gains univocality, the percept is reported to gain in the feeling of familiarity or recognition and to acquire meaning.

#### AN ILLUSTRATIVE EXPERIMENT<sup>2</sup>

In order to provide a clear example of such learning, we studied the development of a single identifying response. The *S* was presented with a visual item consisting of a nonsense "scribble"; his recognition of it was tested when it was interspersed in a series of similar scribbles, and then the single showing and the multiple presentation were repeated until the item could be identified. We devised a set of 17 scribbles intended to be indistinguishable from the critical item on the first trial, and another set of 12 items intended to be distinguishable from the critical item on the first trial.

The items which had to be differentiated are shown in Fig. 1. The critical item, a four-coil scribble, is in the center and 16 other items are arranged outward from it. The eighteenth item (a reversal of the critical item) is not shown. It may be noted that there are three dimensions of variation from the critical item: (a) number of coils—three, four, or five, (b) horizontal compression or stretching, and (c) orientation or right-left reversal. The latter two kinds of variation were produced by photographic transforma-

<sup>2</sup> This experiment was first reported at the meeting of the American Psychological Association in September 1950 in a paper read by Eleanor J. Gibson, and an abstract has been published (6).

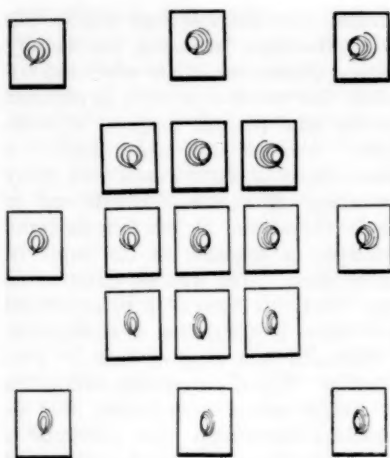


FIG. 1. Nonsense items differing in three dimensions of variation.

tion. There are three degrees of coil frequency, three degrees of compression, and two types of orientation, which yields 18 items. Since one of these is the critical item, 17 remain for use in the experiment. The reader may observe that when these differences are verbally specified and the figures are displayed for immediate comparison, as in Fig. 1, they are clearly distinguishable. The *Ss* of the experiment, however, saw the items only in succession.

The 12 additional items presented on each recognition trial are shown in Fig. 2. Each differs from every other and from all of the

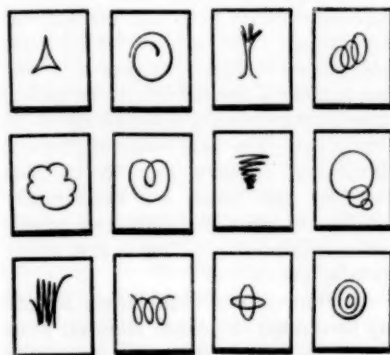


FIG. 2. Nonsense items differing in many dimensions of variation.

set of 18. The differences from the scribbles were intended to be sufficient to make them appear different at the outset to Ss with a normal amount of experience with drawn forms. The 30 items (12 plus 18) were printed photographically on stiff 2 in.  $\times$  4 in. cards with black borders, and made into a pack. The material available for any one learning trial consisted of the critical item plus a shuffled pack of cards among which were interspersed four replicas of the critical item.

The S was shown the critical item for about 5 sec. and told that some of the items in the pack would be exactly like the one shown. The series of 34 was then presented each with a 3-sec. exposure and S was asked to report which of them were the same figure. The identifying response recorded was any report such as "that's it" or "this is the one I saw before." The S was never told whether an identification was correct or incorrect. A record was kept not only of the identifying responses, but also of any spontaneous descriptions offered by S, which were later classified as *naming* responses and *qualifying* responses.

At the end of the first trial the critical figure was presented a second time and another shuffled pack was run through. The procedure of examining a figure and then trying to identify it when mixed with a series including figures of both great and little similarity was continued until S made only the four correct identifications in one trial. Three groups took part in the experiment: 12 adults, 10 older children (8½ to 11 years), and 10 younger children (6 to 8 years).

**Results.** In this experiment, learning is taken to be an increase in the specificity of an identifying response or, in other words, a decrease in the size of the class of items that will elicit the response. The data therefore consist of the number of items (out of a probable maximum of 17) reacted to as if they were the critical figure. As will be evident, this class of undifferentiated items was reduced as a result of repetition. The three groups of Ss, however, began to learn at very different levels and learned at very different rates. The results are given in Table 1. For adults, the class of undifferentiated items at the outset was small (Mean = 3.0), and only a few trials were needed before this class was reduced to the critical item alone (Mean = 3.1). Two of these adults were able to make no other than correct identifying responses on the first trial. Both were psychologists who could have had previous acquaintance with nonsense figures. The learning task was so easy for this group that not much information about the learning process could be obtained. At the other extreme, however, the younger children "recognized" nearly all of the scribbles on the first trial (Mean = 13.4), which

TABLE 1  
INCREASE IN SPECIFICITY OF AN IDENTIFYING RESPONSE FOR THREE AGE GROUPS

Variable	Adults (N = 12)	Older Children (N = 10)	Younger Children (N = 10)
Mean number of undifferentiated items on first trial	3.0	7.9	13.4
Mean number of trials required for completely specific response	3.1	4.7	6.7*
Percentage of erroneous recognitions for items differing in <i>one</i> quality	17	27	53
Percentage of erroneous recognitions for items differing in <i>two</i> qualities	2	7	35
Percentage of erroneous recognitions for items differing in <i>three</i> qualities	0.7	2	28

\* Only two of the younger children achieved a completely specific identification. The mean number of undifferentiated items on the last trial was still 3.9.



is to say that the class of undifferentiated items was large. The number of trials needed to reduce this class to the correct item was so great that most of the Ss could not be required to complete the experiment. Two out of 10 reached the criterion, but for the remainder the trials had to be stopped for reasons of fatigue. After an average of 6.7 trials the mean number of undifferentiated items was still 3.9. One child had so much difficulty with the task that *E* finally gave differential reinforcement by saying "right" or "wrong" after each presentation of a card. Although this procedure helped, wholly specific identifications were never achieved. The failures of the younger children to discriminate did not seem to be due merely to "inattention"; they understood that they were to select only the figures which were *exactly* the same as the critical figure.

For the older children (between 8½ and 11 years of age) the results were intermediate between these extremes. For them the particular task and the particular items were neither too hard nor too easy. The average number of undifferentiated items on the first trial was 7.9, and all children succeeded in reducing this to a single item after a mean of 4.7 trials.

Table 1 also indicates for each group an important fact about the unspecific responses: they tend to occur more often as the differences between the test item and the critical item become fewer. As Fig. 1 shows, a given scribble may differ in *one* quality or dimension (thickness, coil frequency, or orientation), or in *two* of these qualities, or in all *three* of them. Five of the scribbles differ in one feature, eight differ in two features, and four differ in three features. It will be recalled that the 12 additional forms shown in Fig. 2 differed from the critical item with respect to *more* than three features. Amount of difference can be

usefully stated as number of differing qualities or, conversely, amount of sameness as the fewness of differing qualities.<sup>3</sup> The lower half of Table 1 gives the percentage of occurrence of false recognitions in the case of scribbles with one quality different, with two qualities different, and with three qualities different. These percentages are based on the number of times the items in question were presented during the whole series of trials. The "dissimilar" figures, which had many qualities different, yielded a zero percentage of false recognitions except for a few scattered instances among the younger children.

*Discussion.* The results show clearly that the kind of perceptual learning hypothesized has occurred in this experiment. A stimulus item starts out by being indistinguishable from a whole class of items in the stimulus universe tested, and ends by being distinguishable from all of them. The evidence for this assertion is that the specificity of S's identifying response has increased. What has happened to produce this result?

The Ss were encouraged to describe all the items of each series as they were presented, and a special effort was made to obtain and record these spontaneous verbal responses for seven of the older children. In general they tended to fall into two types, either naming responses or qualifying responses. Considering only the responses to the 17 scribbles, the record showed that the frequency of the latter type increased during the progress of learning. Examples of the former are nouns like *figure 6*, *curl*, *spiral*, *scroll*. Examples of the latter are adjectival phrases like *too thin*,

<sup>3</sup> Experiments on primary stimulus generalization have usually varied the magnitude of a *single* difference, not the number of differences, between the critical stimulus and the undifferentiated stimulus. However, our method of quantifying "amount of difference" has much to recommend it.

*rounder, reversed.* It is notable that the latter are responses not to the item as such but to the relation between it and the critical item. They are analogous to differential judgments in a psychophysical experiment. An adjective, in general, is a response which is specific not to an object but to a property of two or more objects. It is likely, then, that the development of a specific response to an item is correlated with the development of specific responses to the qualities, dimensions, or variables that relate it to other items. The implication is that, for a child to identify an object, he must be able to identify the differences between it and other objects, or at least that *when* he can identify an object he *also* can identify its properties.

The verbal reactions of the children to the 17 scribbles, both naming and qualifying, could be categorized by *E* as specific or nonspecific to the item in question. These judgments were necessarily subjective, but they were carried out with the usual precautions. Although a single adjective cannot be specific to a single item, a combination of adjectives can be. An example of a nonspecific reaction is "another curlicue," and of a specific reaction is "this one is thinner and rounder." The latter sort may be considered a spontaneously developing identifying reaction, not of the "that's it" type, it is true, but nevertheless fulfilling our definition. The mean number of such verbal reactions on the first trial was 7.7 out of 17, or 45 per cent. The mean number of such reactions on the last trial was 16.5, or 97 per cent. This suggests that, as a single identifying response becomes increasingly specific to one member of a group of similar items, verbal identifying responses also tend to become specific to the other members of the group. As the class of indistinguishable items which will elicit one response is dimin-

ished, the number of responses which can be made to the class increases.

#### OTHER EVIDENCE

Another source of experimental evidence about perceptual learning comes from psychophysics. Contrary to what might be expected, psychophysical experimenters over the years have shown a lively interest in perceptual learning, or at least in the bettering of perceptual judgments with practice. One of the authors has recently surveyed this neglected literature insofar as it concerns improvement of perception or increase in perceptual skills (5). There is a great quantity of evidence about progressive change in acuity, variability, and accuracy of perception, including both relative judgments and absolute judgments. It proves beyond a shadow of doubt that the notion of fixed thresholds for a certain set of innate sensory dimensions is oversimplified. Discrimination gets better with practice, both with and without knowledge of results. An example may be taken from the two-point threshold on the skin.

As long ago as 1858 it was discovered that there is a certain distance at which two points are felt double by a blindfolded subject that is characteristic of the area of the skin tested. At the same time, it was found that only a few hours of practice in this discrimination had the effect of reducing the distance to half of what it had been (17). Later experiments showed that the lowering of the threshold continued slowly for thousands of trials; for instance, it might go from 30 mm. to 5 mm. during four weeks of training. Moreover, the improved discrimination transferred to other untrained areas of the skin, transfer being nearly complete for the bilaterally symmetrical area. It was found that blind subjects had very much lower thresholds than seeing subjects even at the beginning of testing

(12, 18). The experimental improvement was largely lost after a period of disuse. It seemed to depend on confirmation or correction of the judgment, or, in the absence of that, on the development of a sort of scale from "close together" to "far apart" (5). It is clear that any theory of supposedly distinct sensations of oneness and twoness never had any support from these data. As one writer put it, the observer adopts different and finer *criteria* of doubleness. What might these criteria be? We suggest that the stimulation is complex, not simple, and that the observer continues to discover higher-order variables of stimulation in it. The percept becomes differentiated.

#### CONCLUSION

There is no evidence in all of this literature on perceptual learning, nor is there evidence in the experiment reported in the last section, to *require* the theory that an accurate percept is one which is enriched by past experience, whereas a less accurate percept is one *not* enriched by past experience. Repetition or practice is necessary for the development of the improved percept, but there is no proof that it incorporates memories. The notion that learned perception is less and less determined by external stimulation as learning progresses finds no support in these experiments. The observer sees and hears more, but this may be not because he imagines more, or infers more, or assumes more, but because he discriminates more. He is more sensitive to the variables of the stimulus array. Perhaps the ability to summon up memories is merely incidental to perceptual learning and the ability to differentiate stimuli is basic. Perhaps the dependence of perception on learning and the dependence of perception on stimulation are not contradictory principles after all.

This theoretical approach to perceptual learning, it must be admitted, has points of weakness as well as points of strength. It accounts for veridical perception, but it does not account for misperception. It says nothing about imagination or fantasy, or wishful thinking. It is not an obviously useful approach for the study of abnormal behavior or personality, if one is convinced that a man's perceptions are the clues to his motives. But if one is concerned instead with the practical question of whether training can affect favorably a man's perception of the world around him, a very productive field for theory and experiment is opened up.

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## THE PRINCIPLE OF CONGRUITY IN THE PREDICTION OF ATTITUDE CHANGE

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The theoretical model presented in this paper, while not pretending to take account of all variables relating to attitude change, does attempt to cover those variables believed to be most significant with respect to the direction of change to be expected in any given situation. These variables are (a) existing attitude toward the source of a message, (b) existing attitude toward the concept evaluated by the source, and (c) the nature of the evaluating assertion which relates source and concept in the message. Predictions generated by the theory about the directions and relative amounts of attitude change apply to both sources and the concepts they evaluate.

### UNDERLYING NOTIONS

Our work on attitude theory and measurement is an outgrowth of continuing research on experimental semantics, particularly the development of objective methods for measuring meaning (4, 5). From this viewpoint, the *meaning* of a concept is its location in a space defined by some number of factors or dimensions, and *attitude* toward a concept is its projection onto one of these dimensions defined as "evaluative." In the factor analytic work we have done so far, the first and most heavily loaded factor is always one clearly identifiable as evaluative by the labels of the scales it represents, e.g., good-bad, fair-unfair, valuable-worthless, pleasant-unpleasant, and the like. This conception of attitude as a dimension or factor in total meaning has a number of implications, including those

explored in the present paper. It implies, for example, that people having the same attitude toward a concept, such as NEGRO, may be sharply differentiated in terms of other dimensions of the semantic space (e.g., some perceiving NEGRO as powerful and active, others as weak and passive).<sup>1</sup>

Attitudes toward the various objects of judgment associated in messages must be measured in the same units if comparative statements about attitude change are to be made. There have been attempts to devise *generalized attitude scales* in the history of this field (cf. 6, 7), but if one is to judge by the criterion of acceptance and use, they have not been outstandingly successful. In applying the *semantic differential* (a label that has come to be applied to our measuring instrument), various objects of judgment, sources and concepts, are rated against a standard set of descriptive scales. To the extent that location on the evaluative dimension of the semantic differential is a reliable and valid index of attitude (as determined by correlation with other criteria), it is then necessarily a generalized attitude scale. We have some evidence for validity<sup>2</sup> and more is being ob-

<sup>1</sup> A study in progress exhibits precisely this phenomenon with respect to the concept NEGRO. Similar findings are evident with respect to THE CHURCH and CAPITAL PUNISHMENT.

<sup>2</sup> For example, the correlations between scores on the evaluative scales of the semantic differential and scores on the Thurstone scales on attitude toward THE CHURCH, NEGRO, and CAPITAL PUNISHMENT are .74, .82, and .81, respectively.



tained; reliability of the differential, particularly the evaluative dimension, is reasonably high, running in the .80's and .90's in available data.

Another underlying notion about human thinking we have been exploring is that *judgmental frames of reference tend toward maximal simplicity*. Since extreme, "all-or-nothing" judgments are simpler than finely discriminated judgments of degree, this implies a continuing pressure toward polarization along the evaluative dimension (i.e., movement of concepts toward either entirely good or entirely bad allocations). We have evidence that extreme judgments have shorter latencies than more discriminative judgments (5), and that extreme judgments are characteristic of less intelligent, less mature, less well educated, or more emotionally oriented individuals (8). Furthermore, since assumption of identity is a simpler process than maintenance of distinction, this also implies a continuing pressure toward elimination of differences among concepts which are localized in the same direction of the evaluative framework. We have evidence that in the judging of emotionally polarized concepts all scales of judgment tend to rotate toward the evaluative, e.g., their correlations with good-bad tend to increase and therefore the relative loading on the evaluative factor tends to increase (5).

The most "simple-minded" evaluative frame of reference is therefore one in which a tight cluster of highly polarized and undifferentiated good concepts is diametrically opposed in meaning to an equally tight and polarized cluster of undifferentiated bad concepts. The same underlying pressure toward simplicity operates on any new or neutral concept to shift it one way or the other. For example, there is the tendency in American thinking, about which Pandit

Nehru complains, requiring that India be either "for us or agin' us." This is, of course, the condition referred to by the general semanticists (e.g., Johnson, 2) as a "two-valued orientation," and it is unfortunately characteristic of lay thinking in any period of conflict and emotional stress. The more sophisticated thinker, according to this view, should show less tendency to polarize, more differentiation among concepts, and thus greater relative use of factors other than the evaluative.

#### THE PRINCIPLE OF CONGRUITY

The principle of congruity in human thinking can be stated quite succinctly: *changes in evaluation are always in the direction of increased congruity with the existing frame of reference*. To make any use of this principle in specific situations, however, it is necessary to elaborate along the following lines: When does the issue of congruity arise? What directions of attitude change are congruent? How much stress is generated by incongruity and how is it distributed among the objects of judgment?

*The issue of congruity.* Each individual has potential attitudes toward a near infinity of objects. It is possible to have varying attitudes toward diverse concepts without any felt incongruity or any pressure toward attitude change, as long as no association among these objects of judgment is made. As anthropologists well know, members of a culture may entertain logically incompatible attitudes toward objects in their culture (e.g., ancestor worship and fear of the dead) without any stress, as long as the incompatibles are not brought into association. The issue of congruity arises whenever a message is received which relates two or more objects of judgment via an assertion.

The simplest assertion is merely a *descriptive statement*: "Chinese cooking is good," "Jefferson was right," "This neurotic modern art." To the extent that the evaluative location of a particular qualifier differs from that of the thing qualified, there is generated some pressure toward congruity. Similar pressure is generated by ordinary *statements of classification*: "Senator McCarthy is a Catholic," "Tom is an ex-con," "Cigarettes contain nicotine." To the extent that the evaluative locations of instance and class are different, some pressure toward congruity exists. A more complex situation is that in which a *source makes an assertion about a concept*: "University President Bans Research on Krebiozen"; "Communists like strong labor unions." This is the most commonly studied situation, and one for which we have some empirical data against which to test our hypotheses. Assertions may be explicit linguistic statements of evaluation or implicit behavioral, situational statements. A newsphoto of Mrs. Roosevelt smiling and shaking hands with a little colored boy is just as effective in setting up pressures toward congruity as a verbal statement on her part.

*Directions of congruence and incongruence.* To predict the direction of attitude change from this general principle it is necessary to take into account simultaneously the existing attitudes toward each of the objects of judgment prior to reception of the message and the nature of the assertion which is embodied in the message. Attitudes can be specified as favorable (+), neutral (0), and unfavorable (-). Assertions can be specified as positive or associative (+) or negative or disassociative (-). They may also, of course, include evaluative loading (e.g., when X denounces Y, we have both a disassociative asser-

tion and negative evaluation of Y). When attitudes toward both objects of judgment are polar, the nature of the assertion determines congruence or incongruence. For EISENHOWER (+) to come out in favor of FREEDOM OF THE PRESS (+) is, of course, congruent with the existing frame of reference of most people in this country, but for THE DAILY WORKER (-) to speak in favor of FREEDOM OF THE PRESS (+) is attitudinally incongruent. In this simplest of states in which human thinking operates, sources we like should always sponsor ideas we like and denounce ideas we are against, and vice versa.

When the existing attitude toward one of the objects of judgment is neutral and the other polar, we must speak of what directions *would be* congruent. If, for example, a favorable source like EISENHOWER were to make a favorable assertion about the MINISTER FROM SIAM (a neutral notion to most of us), it would be congruent *if* the latter were also favorable—hence pressure is generated toward attitude change in this direction. If PRAVDA (-) sponsors GRADUAL DISARMAMENT (0), the pressure is such as to make the relatively neutral notion of disarmament less favorable; similarly, if a PROFESSOR (0) as a source favors PREMARITAL SEXUAL RELATIONS (-) as making for better marriages, it is the PROFESSOR that becomes less favorable (this is not unlike the "guilt by association" technique). Conversely, for our neutral PROFESSOR (0) to speak out against MORAL DEPRAVITY (-) must have the effect of raising his esteem (this is the familiar "I am against sin" technique).

When both objects of judgment are neutral, there is no question of congruity between them, and movement is determined solely by the nature of the assertion, i.e., this becomes a case

of simple qualification or classification. If MR. JONES denounces MR. SMITH, neither of whom is known, there is presumably some negative pressure on MR. SMITH by virtue of the sheer devaluation of "being denounced." Since the evaluation applies to the concept and not the source, the effect should be chiefly upon the concept. We shall find evidence for such an "assertion effect" in the available data.

We may now make a general statement governing the direction of congruence which will hold for any object of judgment, source or concept, and any type of assertion.

1. *Whenever one object of judgment is associated with another by an assertion, its congruent position along the evaluative dimension is always equal in degree of polarization (d) to the other object of judgment and in either the same (positive assertion) or opposite (negative assertion) evaluative direction.*

This is to say that we have attitude scores toward two objects of judgment,  $OJ_1$  and  $OJ_2$ , and to each of these scores we assign a value,  $d$ , which represents the degree of polarization of that attitude. Thus we have  $d_{OJ_1}$  and  $d_{OJ_2}$ . Since the measuring instrument which has been used in our quantitative work so far (the semantic differential) treats the evaluative dimension as a 7-step scale with "4" defined as the neutral point, we have three degrees of polarization in each direction, i.e., +3, +2, +1, 0, -1, -2, -3. Given  $OJ_1$  and  $OJ_2$  associated with one another through either a positive ( $OJ_1A+OJ_2$ ) or negative ( $OJ_1A-OJ_2$ ) assertion, we define the congruent position ( $C$ ) of either object of judgment as follows:

If  $OJ_1A+OJ_2$ , then

$$d_{COJ_1} = d_{OJ_2}, \quad [1]$$

$$d_{COJ_2} = d_{OJ_1}. \quad [2]$$

If  $OJ_1A-OJ_2$ , then

$$d_{COJ_1} = -d_{OJ_2}, \quad [3]$$

$$d_{COJ_2} = -d_{OJ_1}. \quad [4]$$

Figure 1 provides some graphic illustrations. In example 1, we have a positive assertion (indicated by the + on the bar connecting source and concept) associating two equally favorable objects of judgment; in this situation maximum congruity already exists. In all the other illustrations given, the existing positions are not those of maximum congruence, and those positions which would be maximally congruent for each object of judgment are shown by dashed circles. In situation 3, for example, a congruent source would be at -2 and a congruent concept would be at +3, given the favorable assertion between two items of opposite sign.

*Magnitude and distribution of pressure toward congruity.* Knowing the existing locations of maximum congruence under the given conditions (by applying Principle 1), it becomes possible to state the amount and

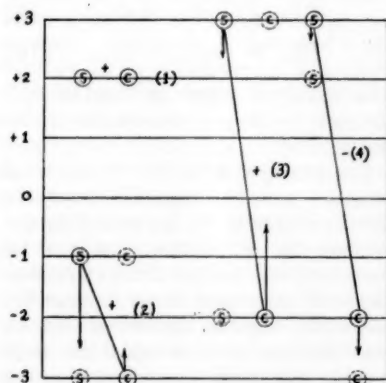


FIG. 1. Graphic examples of four situations in which a source (s) makes an assertion (+ or -) about a concept (c). Positions of maximum congruity are indicated by dashed circles; predicted changes in attitude are indicated by arrows. See discussion in text.

direction of application of total available pressure toward congruity.

2. *The total available pressure toward congruity (P) for a given object of judgment associated with another by an assertion is equal to the difference, in attitude scale units, between its existing location and its location of maximum congruence along the evaluative dimension; the sign of this pressure is positive (+) when the location of congruence is more favorable than the existing location and negative (-) when the location of congruence is less favorable than the existing location.*

That is,

$$P_{OJ_1} = d_{COJ_1} - d_{OJ_1}, \quad [5]$$

$$P_{OJ_2} = d_{COJ_2} - d_{OJ_2}. \quad [6]$$

Therefore, substituting from equations 1 through 4,

if  $OJ_1A+OJ_2$ ,

$$P_{OJ_1} = d_{OJ_2} - d_{OJ_1}, \quad [7]$$

$$P_{OJ_2} = d_{OJ_1} - d_{OJ_2}. \quad [8]$$

If  $OJ_1A-OJ_2$ ,

$$P_{OJ_1} = -d_{OJ_2} - d_{OJ_1}, \quad [9]$$

$$P_{OJ_2} = -d_{OJ_1} - d_{OJ_2}. \quad [10]$$

The resulting signs of equations 7 through 10 then represent the direction of P.

For example 2 in Fig. 1, the total pressure toward congruity available for the source is -2 units and for the concept is +2 units. As can be seen by inspection of these examples, the total pressures toward congruity for both objects associated by an assertion are always equal in magnitude, although they may be the same or different in sign (i.e.,  $|P_{OJ_1}| = |P_{OJ_2}|$ ). The upper figures in each cell of Table 2 give the total pressures and directions of application for all possible relations

among sources and concepts and both types of assertions. These computations are based upon the assumption of a 7-step scale with three degrees of polarization possible in each evaluative direction; they may be treated as general index numbers.

The third principle with which we shall operate incorporates the empirical generalization that intense attitudes are more resistant to change than weakly held ones (cf., 1, 3, 9), but does so in a way which generates more detailed predictions.

3. *In terms of producing attitude change, the total pressure toward congruity is distributed between the objects of judgment associated by an assertion in inverse proportion to their separate degrees of polarization.*

In other words, relatively less polarized objects of judgment, when associated with relatively more polarized objects of judgment, absorb proportionately greater amounts of the pressure toward congruity, and consequently change more.

Applying Principle 3 above, it is possible to predict relative attitude change according to the following formulas:

$$AC_{OJ_1} = \frac{|d_{OJ_2}|}{|d_{OJ_1}| + |d_{OJ_2}|} P_{OJ_1}, \quad [11]$$

$$AC_{OJ_2} = \frac{|d_{OJ_1}|}{|d_{OJ_1}| + |d_{OJ_2}|} P_{OJ_2}, \quad [12]$$

where AC refers to attitude change; where  $d_{OJ_1}$  and  $d_{OJ_2}$  are taken at their absolute values regardless of sign, and where  $P_{OJ_1}$  and  $P_{OJ_2}$  are determined from equations 7 through 10. Thus, the sign of the right-hand side of the equation is always that of the particular  $P_{OJ}$  under consideration, and thus represents the direction of change. In example 1 in Fig. 1, there is no pressure and hence no change. In the other examples solid arrows indi-

TABLE 1  
PREDICTED ATTITUDE CHANGE FOR CONCEPT AS A FUNCTION OF ORIGINAL LOCATIONS  
OF BOTH SOURCE AND CONCEPT—POSITIVE ASSERTION  
(Uncorrected for incredulity)

Original Attitude Toward Source	Original Attitude Toward Concept						
	+3	+2	+1	0	-1	-2	-3
+3	0.0	+0.6	+1.5	+3.0	+3.0	+3.0	+3.0
+2	-0.4	0.0	+0.7	+2.0	+2.0	+2.0	+2.0
+1	-0.5	-0.3	0.0	+1.0	+1.0	+1.0	+1.0
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-1	-1.0	-1.0	-1.0	-1.0	0.0	+0.3	+0.5
-2	-2.0	-2.0	-2.0	-2.0	-0.7	0.0	+0.4
-3	-3.0	-3.0	-3.0	-3.0	-1.5	-0.6	0.0

cate the direction and magnitude of predicted change. In example 2, the source must absorb twice as much pressure as the more polarized concept, and in a negative rather than a positive direction (e.g., BULGARIA -1 sponsors HATE CAMPAIGN -3). The unexpected prediction here, that the even more unfavorable concept, HATE CAMPAIGN, actually becomes a little less unfavorable under these conditions, derives directly from the theoretical model and will be discussed later.

If we associate  $OJ_1$  with the source of an assertion, and  $OJ_2$  with the concept, the numbers in Table 1 represent the results of applying formula 12 to the prediction of attitude change toward the concept for all combinations of original attitude toward source and concept when the assertion is positive.

Note that for all *incongruous relations* the predicted change is constant for a given original attitude toward source (upper right and lower left corners of matrix)—a highly favorable

source favoring a negative concept produces just as much attitude change when that concept is -3 as when it is -1. This prediction assumes complete credulity of the message on the part of the receiver, a condition that exists only rarely, in all probability, for incongruous messages. Certainly, when presented with the incongruous message, EISENHOWER sponsors COMMUNISM, in an experimental situation, very few subjects are going to give it full credence. If we are going to make predictions, it is apparent that the variable of credulity must be taken into account.

4. *The amount of incredulity produced when one object of judgment is associated with another by an assertion is a positively accelerated function of the amount of incongruity which exists and operates to decrease attitude change, completely eliminating change when maximal.*

Since incongruity exists only when similarly evaluated concepts are associated by negative assertions or when oppositely evaluated concepts are



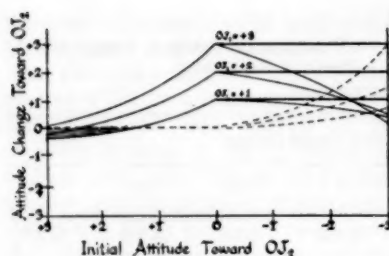


FIG. 2. Predicted change in attitude toward  $OJ_2$  and correction for incredulity (postulated incredulity indicated by dashed lines).

associated by positive assertions, the correction for incredulity is limited to the upper right and lower left corners of the matrix in Table 1. Within these situations, the amount of this correction is assumed to increase with the degree of incongruity, e.g., with the total pressure toward congruity available. It is assumed that no incongruity, and hence no incredulity, can exist where one of the objects of judgment is neutral, e.g., EISENHOWER may come out either for or against a neutral concept like ST. LAWRENCE WATERWAY without the issue of incredulity arising. It is realized, of course, that other factors than those discussed here may affect incredulity.

Figure 2 provides graphic illustration of the corrections made for incredulity. The original curves, level for the neutral point and beyond, derive from the upper right corner of Table 1 and represent three degrees of favorable original attitude toward the source ( $OJ_1$ ). The dashed lines represent postulated incredulity, positively accelerated functions of total pressure toward congruity. The shape of this function is, of course, based on pure hunch and will probably have to be modified; it simply seems reasonable that a person's tendency to reject a message will be relatively

much less for slightly incongruous relations (e.g., EISENHOWER +3 praises BULGARIANS -1) than for grossly incongruous ones (e.g., EISENHOWER +3 praises COMMUNISM -3). The light solid curves represent the result of subtracting incredulity functions from predicted attitude changes. The corrected values are given in Table 2. The same corrections, with appropriate regard to sign, apply to the lower left corner of Table 1 and are made in Table 2. For incongruous situations, then, the formulas for predicting attitude change become:

$$AC_s = \frac{|d_c|}{|d_s| + |d_c|} P_s \mp i, \quad [13]$$

$$AC_c = \frac{|d_s|}{|d_s| + |d_c|} P_c \mp i, \quad [14]$$

where the sign of the second factor ( $i$  = correction for incredulity) is always opposite to that of the first factor, i.e., of  $P$ , and thus serves to diminish the effect. The notations  $s$  and  $c$  refer, of course, to source and concept, respectively.

It is to be emphasized that formulas 13 and 14 apply only to situations of incredulity, or, to put it another way,  $i = 0$  for all credulous situations. The precise nature of the  $i$  function remains to be empirically determined. The curve we have assumed for  $i$  approximates the function  $i = a(d_s^2 + b)(d_c^2 + d_c)$ , where the constants  $a$  and  $b$  are  $1/40$  and  $1$  respectively. It is clear, however, that  $i = f(d_s, d_c)$ , and hence the attitude change is still a function of the two degrees of polarization and of direction of the assertion.

Incredulity, to the extent it is present, will not only operate to "damp" changes in attitude but should also appear in expressions of disbelief and rationalization. This makes it possible to ascertain the in-

credulity function independent of attitude change. A proposed experiment along these lines might be as follows: If subjects are presented with a number of messages and told that some are valid and others faked, we would expect the frequency of "fake" judgments to be some increasing function of the measured amount of incongruity (e.g., in terms of locations of original attitudes toward the associated objects of judgment). It is the shape of this function in which we would be particularly interested. If the same subjects were then assured that certain of the "fake" messages were actually valid, we would expect to record rationalizations and other attempts to interpret the message without modifying the evaluative

frame of reference; e.g., told that RUSSIA is actually sponsoring a PEACE CONFERENCE, the subject is likely to rationalize this event as some subterfuge on the part of the Soviets in the Cold War. Use of the same messages on another group of subjects in a standard pre- and postmessage attitude change design should serve to test the prediction that attitude change for incongruous assertions is damped in proportion to the degree of incredulity produced.

This independence of credulity as a variable also means that it should be possible to approximate the attitude change values in Table 1 (uncorrected) under special conditions where credulity is made more probable. For example, if EISENHOWER

TABLE 2  
TOTAL PRESSURE TOWARD CONGRUITY (UPPER NUMBERS) AND PREDICTED CHANGES IN ATTITUDE (LOWER NUMBERS) AS CORRECTED FOR INCREDULITY\*  
(Positive assertion)\*\*

Initial Location of $OJ_1$	Initial Location of $OJ_1$							
	+3	+2	+1	0	-1	-2	-3	M
+3	0 0.0	+1 +0.6	+2 +1.5	+3 +3.0	+4 +2.6	+5 +1.5	+6 0.0	+1.3
+2	-1 -0.4	0 0.0	+1 +0.7	+2 +2.0	+3 +1.8	+4 +1.3	+5 +0.5	+0.8
+1	-2 -0.5	-1 -0.3	0 0.0	+1 +1.0	+2 +0.9	+3 +0.7	+4 +0.4	+0.3
0	-3 0.0	-2 0.0	-1 0.0	0 0.0	+1 0.0	+2 0.0	+3 0.0	0.0
-1	-4 -0.4	-3 -0.7	-2 -0.9	-1 -1.0	0 0.0	+1 +0.3	+2 +0.5	-0.3
-2	-5 -0.5	-4 -1.3	-3 -1.8	-2 -2.0	-1 -0.7	0 0.0	+1 +0.4	-0.8
-3	-6 0.0	-5 -1.5	-4 -2.6	-3 -3.0	-2 -1.5	-1 -0.6	0 0.0	-1.3
/M/	0.3	0.6	1.1	1.7	1.1	0.6	0.3	

\* The  $OJ$  whose change is being predicted, either source or concept, is always  $OJ_1$  and the other is  $OJ_2$ .

\*\* When dealing with negative assertions, reverse the sign of  $OJ_1$  and look in that row.

were actually to invite important COMMUNIST PARTY OFFICERS to a friendly dinner at the White House, the effects on devaluating EISENHOWER and vice versa should be extreme. The greater effectiveness of "event" as compared to "word" propaganda follows directly.

The lower numbers in each cell in Table 2 represent the predicted magnitudes and directions of attitude change for all combinations of original attitude—for SOURCES or CONCEPTS and for either positive assertions or negative assertions (see instructions in table footnotes)—as computed by applying formulas 11 and 12, or 13 and 14 in the case of incongruous assertions. Let us take illustration 2 in Fig. 1 as an example: the original attitudes in this case are  $-1$  (source) and  $-3$  (concept), so we will be concerned with the cell defined by these values. Looking first for SOURCE CHANGE (e.g., SOURCE as  $OJ_1$ ), we find a total pressure toward congruity of  $-2$  (upper figure in cell) and a predicted attitude change of  $-1.5$ ; looking then for CONCEPT CHANGE (e.g., CONCEPT as  $OJ_1$ ), we find a total pressure of  $+2$  and a predicted attitude change of  $+0.5$ . If this were the message BULGARIA praises COMMUNISM, we might expect a considerable increase in unfavorableness toward BULGARIA and a slight decrease in unfavorableness toward COMMUNISM. The reader may check the other illustrations against Table 2 if he wishes.

Predictions about attitude change are assumed to hold for any situation in which one object of judgment is associated with another by an assertion. In the special source-concept situation, we must take one additional factor into account—the fact that the *assertion itself*, whether positive or negative, typically applies to the concept rather than to the source. When

X praises Y, the favorable effect of "praise" applies chiefly to Y; when X denounces Y, similarly, the unfavorable effect of "denounce" applies chiefly to Y. In other words, we must add to the equation predicting attitude change for concepts a constant ( $\pm A$ ) whose sign is always the same as that of the assertion. In the data we have available, the existence of such an assertion constant applying to the concept but not the source is clearly evident.

#### A TEST OF THE CONGRUITY PRINCIPLE<sup>3</sup>

On the basis of a pretest of 36 potential objects of judgment, three source-concept pairs were selected which met the criteria of (a) approximately equal numbers of subjects holding favorable, neutral, and unfavorable original attitudes toward them, and (b) lack of correlation between attitude toward the source and the concept making up each pair. The three source-concept pairs finally selected were: LABOR LEADERS with LEGALIZED GAMBLING, CHICAGO TRIBUNE with ABSTRACT ART, and SENATOR ROBERT TAFT with ACCELERATED COLLEGE PROGRAMS. Another group of 405 college students was given a *before-test*, in which the 6 experimental concepts along with 4 "filler" concepts were judged against a form of the semantic differential including 6 scales highly loaded on the evaluative factor. The sum of ratings on these six 7-step scales constituted the attitude score for each concept, these scores ranging from 6 (most unfavorable) to 42 (most favorable). Five weeks later the same subjects were given highly realistic newspaper stories including positive or negative assertions involving the experimental source-concept pairs.

<sup>3</sup> This experiment is described in detail in a separate report by one of the authors (9).

TABLE 3  
PREDICTED (UPPER VALUES IN CELLS) AND  
OBTAINED (LOWER VALUES IN CELLS)  
CHANGES IN ATTITUDE

Original Attitude Toward Source	Positive Assertions			Negative Assertions		
	Original Attitude Toward Concept			Original Attitude Toward Concept		
	+	0	-	+	0	-
Source Changes						
+	+0.2 +25	0.0 +16	-1.1 -42	-1.1 -45	0.0 +1	+0.2 +34
0	+2.0 +150	0.0 +25	-2.0 -94	-2.0 -68	0.0 +17	+2.0 +96
-	+1.1 +49	0.0 +13	-0.2 -7	-0.2 -33	0.0 -3	+1.1 +34
Concept Changes						
+	+0.2 +31	+2.0 +245	+1.1 +107	-1.1 -88	-2.0 -180	-0.2 -39
0	0.0 +39	0.0 +80	0.0 +48	0.0 -72	0.0 -79	0.0 -34
-	-1.1 -24	-2.0 -52	-0.2 -10	+0.2 +19	+2.0 +22	+1.1 +16

Immediately afterward the subjects were given the *after-test*, again judging the same concepts against the semantic differential.

Original attitudes toward each source and concept were determined from the before-test scores, subjects being distributed into nine cells,  $S_{+C+}$ ,  $S_{+C0}$ ,  $S_{+C-}$ ,  $S_{0C+}$ , etc. Attitude change amounts, for both source and concept, were obtained by subtracting the before-test score from the after-test score for each subject, a positive value thereby indicating increased favorableness.

Table 3 compares predicted attitude change scores (upper number in each cell) with obtained attitude change scores (lower number in each cell) for both sources and concepts and for both positive and negative assertions. The predicted values represent the algebraic mean of the atti-

tude change scores in appropriate cells of Table 2 (e.g., the value for  $S_{+C+}$  with a positive assertion equals the average for the nine cells in the upper left corner); the obtained values represent the total attitude change scores, summed algebraically, for 45 subjects (15 subjects on each of 3 stories) on 6 evaluative scales. The reason for the gross difference in absolute magnitudes of predicted and obtained scores is therefore that the former are expressed in scale units and the latter in group totals. The general correspondence between predicted and obtained directions of attitude change is apparent from inspection of Table 3. In every case predicted positive changes (+) and predicted negative changes (-) show corresponding signs in the obtained data, and predicted lack of change (0) generally yields obtained changes of small magnitude.

The predictions obviously hold better for source changes than for concept changes, and it will be recalled that it was also predicted that an *assertion constant* ( $\pm A$ ) would apply to the concept but not the source. This would mean that for comparable situations (e.g.,  $S_{+C0}$  vs.  $S_{0C+}$ ,  $S_{0C-}$  vs.  $S_{-C0}$ , etc.) concept changes should be more in the favorable direction than source changes for positive assertions and more in the negative direction for negative assertions. Table 4 provides a test of this prediction. As can be seen, when comparable conditions for source and concept changes are arranged, the differences in magnitudes of attitude change are regularly positive for positive assertions (concept changes more toward favorable direction) and regularly negative for negative assertions (concept changes more toward unfavorable direction). With 17 of the 18 values in the predicted direction, this is obviously significant.

A rough estimate of the size of this constant can be obtained from the average difference between source and concept changes for comparable situations: it turns out to be  $A = \pm 46$  in total change score or  $A = .17$  in units of the 7-step attitude scale employed. In other words, under the general conditions of this experiment, the assertion constant applied to concept changes equals about 1/6 of a scale unit.

That the magnitudes of attitude changes as well as their directions tend to follow predictions is also evident by inspection of Table 3. This can be seen more clearly in the correlation plot between predicted changes and obtained changes given as Fig. 3. The predicted values are here treated as categorical and the obtained as

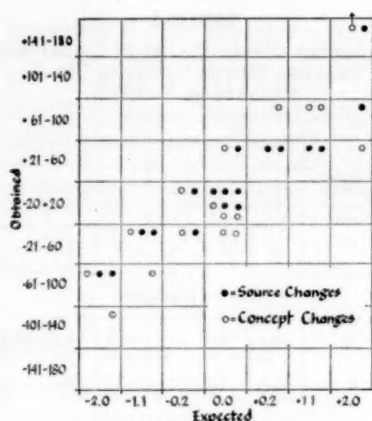


FIG. 3. Correlation plot between predicted and obtained attitude changes after corrections for incredulity and for constant effect of assertion.

TABLE 4  
EFFECTS OF ASSERTION ITSELF (A)

Source	Concept	Difference (A)
Positive Assertions (Predicted that A is +)		
$S_{+L_{+}} + 25$	$S_{+C_{+}} + 51$	+ 26
$S_{+L_{+}} + 150$	$S_{+C_{+}} + 245$	+ 95
$S_{+L_{+}} + 49$	$S_{+C_{+}} + 107$	+ 58
$S_{+L_{+}} + 16$	$S_{+C_{+}} + 39$	+ 23
$S_{+L_{0}} + 25$	$S_{+C_{0}} + 80$	+ 55
$S_{+L_{0}} + 13$	$S_{+C_{0}} + 48$	+ 35
$S_{+L_{-}} - 42$	$S_{+C_{-}} - 24$	+ 18
$S_{+L_{-}} - 94$	$S_{+C_{-}} - 52$	+ 42
$S_{+L_{-}} - 7$	$S_{+C_{-}} - 10$	- 3
Negative Assertions (Predicted that A is -)		
$S_{+L_{+}} - 45$	$S_{+C_{+}} - 88$	- 43
$S_{+L_{+}} - 68$	$S_{+C_{+}} - 180$	-112
$S_{+L_{+}} - 33$	$S_{+C_{+}} - 39$	- 6
$S_{+L_{0}} + 1$	$S_{+C_{0}} - 72$	- 73
$S_{+L_{0}} + 17$	$S_{+C_{0}} - 79$	- 96
$S_{+L_{0}} - 3$	$S_{+C_{0}} - 34$	- 31
$S_{+L_{-}} + 34$	$S_{+C_{-}} + 19$	- 15
$S_{+L_{-}} + 96$	$S_{+C_{-}} + 22$	- 74
$S_{+L_{-}} + 34$	$S_{+C_{-}} + 16$	- 18

continuous, and the latter have been corrected for the assertion constant by adding 46 to concept changes with negative assertions and subtracting 46 from concept changes with positive assertions. The correlation between predicted and obtained changes in attitude is high ( $r = .91$ ).

A number of corollaries derive from the congruity principle, some of which can be tested against Tannenbaum's data and others of which cannot. They are as follows:

1. *Shifts in evaluation always tend toward equalization of the degrees of polarization of the objects of judgment associated by an assertion.* If two unequally polarized concepts are associated, the less polarized one becomes more so and the more polarized less so; if a neutral concept is associated with a polarized one, it always becomes more polarized. In Tannenbaum's data this means that the less polarized object of judgment (neutral) should always change more than the more polarized object of judgment (plus or minus); this holds for all



TABLE 5  
COMPARISON OF ATTITUDE CHANGES FOR  
NEUTRAL AND POLAR OBJECTS  
OF JUDGMENT

Situation	Change for Neutral	Change for Polar
Positive Assertions		
$s_{0c+}$	+150 (s)	- 7 (c)
$s_{+c0}$	+199 (c)	+16 (s)
$s_{-c0}$	- 98 (c)	+13 (s)
$s_{0c-}$	- 94 (s)	+ 2 (c)
Negative Assertions		
$s_{0c+}$	- 68 (s)	-26 (c)
$s_{+c0}$	-134 (c)	+ 1 (s)
$s_{-c0}$	+ 48 (c)	- 3 (s)
$s_{0c-}$	+ 96 (s)	+12 (c)

relevant conditions except one ( $s_{0c+}$ , negative assertion), and even here when correction for the assertion constant is made. The comparisons shown in Table 5, where concept changes have been corrected for the assertion constant, clearly substantiate this prediction—in every case the neutral member shows a large shift and the polar member a small shift.

2. *When the total pressure toward congruity is constant, it is easier to make an object of judgment more polarized than less so.* That this prediction follows from the theory can be seen in Table 2 by comparing magnitudes of attitude change within the same row or column (for a given location of source or concept) when the total pressure is the same in amount but opposite in sign—amount of attitude change is always larger in the same direction as the sign of the row or column. This cannot be checked in Tannenbaum's data because he does not differentiate between degrees of original attitude in the same direction. It would be expected, however, from

our general notion that evaluative frames of reference tend toward maximum simplicity.

3. *Attitude change toward an object of judgment is an inverse function of intensity of original attitude toward that object.* That weakly held attitudes are more susceptible to change is a widely held notion, but it is only valid, according to the present theory, for the *average* of all degrees of attitude toward the other object with which a given one is associated *regardless of sign* (the absolute means,  $|M|$ , given at the bottom of Table 2) or for maximally polarized attitudes toward the other object (+3 and -3 rows in Table 2). The "law" definitely does not hold for other degrees of attitude toward the second object of judgment, as can be seen by inspection of this table. The data in Table 6 compare predicted values (absolute means at bottom of Table 2) with those obtained by Tannenbaum, both being expressed in attitude scale units in this case. The close correspondence in trend is apparent, and the obtained trend is statistically significant. The difference in absolute magnitude presumably represents the limited effect of a single message upon attitude change. The theoretical model as developed so far takes account of neither learning via suc-

TABLE 6  
ATTITUDE CHANGE TOWARD AN OBJECT OF  
JUDGMENT AS A FUNCTION OF ORIGINAL  
ATTITUDE TOWARD THAT OBJECT  
ITSELF

	Original Attitude Toward Object of Judgment		
	+	0	-
Predicted	0.6	1.7	0.6
Obtained (Source)	0.2	0.5	0.2
Obtained (Concept)	0.3	0.7	0.2

TABLE 7  
ATTITUDE CHANGE TOWARD ONE OBJECT OF  
JUDGMENT AS A FUNCTION OF ORIGINAL  
ATTITUDE TOWARD THE OTHER OBJECT  
OF JUDGMENT

Assertions	Original Attitude Toward Other Object		
	+	0	-
Positive			
Predicted	+0.8	0.0	-0.8
Obtained (Source)	+0.3	0.0	-0.2
Obtained (Concept)	+0.3	0.0	-0.3
Negative			
Predicted	-0.8	0.0	+0.8
Obtained (Source)	-0.2	0.0	+0.2
Obtained (Concept)	-0.2	-0.1	+0.2

cessive messages nor of intensity of assertions.

4. *Attitude change for a given object of judgment in the direction of the assertion is an approximately linear function of the favorableness of the original attitude toward the other object of judgment with which it is associated.* The more favorable the attitude toward a source, the greater the effect of a positive assertion on raising attitude toward the concept and the greater the effect of a negative assertion upon lowering attitude toward the concept. Strongly unfavorable sources have just the opposite effects. The same statements hold for changes in attitude toward sources when original attitudes toward concepts are varied. Table 7 compares predicted and obtained values. Again, the generally lower levels of obtained changes as compared with predicted changes are presumably due to the limited effects of a single message. Changes in attitude have been corrected for the assertion constant, here as in Table 6. The obtained functions are in the direction predicted, and their trend is statistically significant.

5. *Whenever a congruent assertion associates two differently polarized objects of judgment, and neither of them is neutral, the more polarized object of judgment becomes less so.* This deduction includes the rather paradoxical situations noted earlier in this paper in which, for example, a highly favorable source comes out in favor of somewhat less favorable concept and becomes slightly less favorable itself in doing so, according to theory. The locations in Table 2 where this prediction arises are italicized. Here we are forced to predict, for example: when EISENHOWER +3 praises GOLFING +1, he loses a little prestige while giving a big boost to the concept; when EISENHOWER +3 denounces COMIC BOOKS -1, he may make the latter considerably more unfavorable, but he loses a little ground himself in the exchange. It is as if a highly favorable source should only favor equally good things or be against extremely bad things and a highly unsavory concept should be only sponsored by equally unsavory sources or condemned by highly noble sources.

If such an effect could be demonstrated, it would be convincing evidence for the whole theory. Tannenbaum's study provides only a partial test for this phenomenon in that the experimental situation probably lacked the necessary sensitivity to get at the very minimal changes predicted. However, of 38 cases that met the necessary conditions, 21 (55.3 per cent) showed relatively small changes in the predicted direction, 15 (39.5 per cent) showed no change, and only 2 (5.3 per cent) changed in the opposite direction.

#### SUMMARY

This paper describes a general theory of attitude change which takes into account original attitude toward

the source of a message, original attitude toward the concept evaluated by the source, and the nature of the evaluative assertion. Predicted changes in attitude toward both source and concept are based upon the combined operation of a principle of congruity, a principle of susceptibility as a function of polarization, and a principle of resistance due to incredulity for incongruous messages. Comparison of predictions with data obtained in a recent experiment provides a test of the theory. No attempt has been made to integrate this particular theoretical model with more general psychological theory, and we feel no urge at this time to attempt such detailed translations. We are, of course, aware that there are many variables other than those considered here which contribute to attitude change.

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## A MODEL OF SHORT- AND LONG-RUN MECHANISMS INVOLVED IN PRESSURES TOWARD UNIFORMITY IN GROUPS

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Leon Festinger and his associates (2) have stated and tested a number of propositions about communication processes in small groups. This paper carries forward the synthesis of these propositions into an interrelated system, differentiating short-run mechanisms from those involved in the long run. First, we shall formalize some of Festinger's propositions and organize them into a model. Then, we shall examine two of the empirical studies in their relation to the mechanisms involved in pressures toward uniformity in groups.

### 1. THE POSTULATED AGGREGATIVE MODEL

Some of Festinger's hypotheses deal with aggregative relations—that is, they are concerned with the members of a group taken as a whole. Others focus on the behaviors of particular individuals in the group.<sup>2</sup> Let us confine our work for the present to his aggregative propositions.

*The Aggregative Variables.* Five of Festinger's hypotheses—those numbered 1a, 1b, 1c, 3a, and 3b—are stated in terms of six aggregative variables, in addition to time.

<sup>1</sup> An earlier version of this paper was presented to the Summer Seminar on Design of Experiments on Decision Processes at Santa Monica in July, 1952. In revising the paper we have had the benefit of valuable comments from Leon Festinger, James Coleman, and Chris Argyris.

<sup>2</sup> A model handling the deviate member has been developed and will be published by the *British Journal of Psychology* under the title "Some Mechanisms Involved in Group Pressures Upon Deviate-Members."

*D(t)*: The perceived *discrepancy* of opinion on an issue among members of a group at time *t*;

*P(t)*: *Pressure* upon members of the group to communicate with each other at time *t*;

*L(t)*: *Receptivity (listening)* of members of the group to influence by communications from other members at time *t*;

*C(t)*: *Strength of the attraction* of individuals to the group (*cohesiveness*) at time *t*;

*U(t)*: *Pressure felt by the group* to achieve *uniformity* of opinion, i.e., to reduce perceived discrepancy of opinion at time *t*;

*R*: *Relevance* of the issue to the group. This variable appears as a parameter, and hence as constant in time.

In constructing the model we shall assume that each variable is some kind of average or aggregate for members of the group. For example, *D* might be measured by locating the opinions of group members on a scale, attaching numbers to scale positions and calculating the standard deviation of the members' opinions in terms of these numbers. Even the intervening variables, although not directly measured, can be thought of as averages of the values for individual members. We will assume that the magnitude of each variable at time *t* for a given group can be represented by a real variable, using the latter term in its mathematical sense.

*Representation of the Hypotheses by Equations.* Festinger's aggregative

propositions (2, pp. 273-277) state relationships between variables, as follows:

Number of the Proposition	Variables Interrelated
1a	$D$ and $P$
1b	$R$ and $P$
1c	$C$ and $P$
3a	Change(s) in $D$ and $U$
3b	Change(s) in $D$ and $C$

We could now translate each of these five propositions into a corresponding mathematical relationship. This would not do justice, however, to their meaning, and might fail to represent adequately the dynamic mechanisms that Festinger implicitly postulates. Instead, we shall set forth a model of five equations which, we believe, constitutes a reasonable interpretation of the mechanisms. Then we shall show the relation of Festinger's explicit propositions to the system we have constructed. The five equations comprising the model are as follows:

$$\frac{dD}{dt} = f[P(t), L(t), D(t)],^3 \quad [1.1]$$

$$P(t) = P[D(t), U(t)], \quad [1.2]$$

$$L(t) = L[U(t)], \quad [1.3]$$

$$\frac{dC}{dt} = g[D(t), U(t), C(t)], \quad [1.4]$$

$$U(t) = U[C(t), R]. \quad [1.5]$$

Note that two of the equations, 1.1 and 1.4, postulate a process of adjustment, of  $D$  and  $C$ , respectively, that takes place gradually over time. The

<sup>3</sup> Read: The time rate of change in the discrepancy of opinion is a function of the pressure to communicate, the receptivity to influence, and the existing discrepancy. The remaining four equations may be read in an analogous fashion. The change in the "is a function of" designation from  $f$  to  $P$  to  $L$  to  $g$  to  $U$  is simply to indicate that the functions involved in the five equations are not necessarily identical in form.

remaining equations, 1.2, 1.3, and 1.5, make  $P$ ,  $L$ , and  $U$ , respectively, change instantaneously with the variables on which they depend. The term "instantaneously" need not, of course, be interpreted literally, but may be taken to mean that the mechanisms represented by these three equations bring about more rapid adjustment in the dependent variable than the mechanisms in the other two. This part of the system enables us to make clear distinctions between the short-run and long-run mechanisms involved in pressures toward uniformity. While the equations permit the values of the variable to change through time, the forms of the equations themselves are assumed to be independent of the length of time the group is in existence.

The propositions are stated so as to involve only *ordinal* and not *cardinal* properties of the variables. This is important, since in the present stage of development of operational definition of the variables the scale units are arbitrary. We can observe that group A is more cohesive than group B, but not that A is twice as cohesive as B, or that the cohesiveness of A exceeds the cohesiveness of B by a greater amount than the cohesiveness of C exceeds the cohesiveness of D. It should be stressed that our treatment does not impose any requirements of measurability not already present, implicitly or explicitly, in Festinger's verbal theory. The equations make statements about certain variables as being "greater" or "less," but precisely the same kinds of statements are required in the verbal theory.

Now let us compare Festinger's propositions with our model.

Hypothesis 1a: *The pressure on members to communicate to others in the group concerning "item x" increases*



*monotonically with increase in the perceived discrepancy in opinion concerning "item x" among members of the group.*

This proposition states that there is a relation between  $P$  and  $D$ , and that a change in the latter brings about a change in the former in the same direction. We have expressed this in equation 1.2 by making  $P$  dependent on  $D$ . To encompass Festinger's proposition we need to add the additional hypothesis that  $P_D > 0$ ; where  $P_D$  symbolizes the partial derivative of  $P$  with respect to  $D$ , and designates the change in  $P$  for a unit change in  $D$  when  $U$  is held constant. If the sign of the derivative is positive (greater than zero), the relation between the variables is of the form, "if  $x_1$  increases,  $x_2$  increases." When the derivative is negative, the relation is the inverse.

Hypothesis 1b: *The pressure on a member to communicate to others in the group concerning "item x" increases monotonically with increase in the degree of "item x" to the functioning of the group.*

This proposition states that there is a relation between  $P$  and  $R$  and that the two vary in the same direction. Festinger also postulates (2, p. 274) that an increase in  $R$  brings about an increase in  $P$  via an increase in  $U$ . These hypotheses are represented by our equations 1.2 and 1.5. To translate the whole of Festinger's hypothesis we need to postulate further that  $P_U > 0$  and  $U_R > 0$ . Note that in this instance Festinger's more formal hypothesis was supplemented by an explanatory discussion linking the more simply stated proposition to other parts of the system.

Hypothesis 1c: *The pressure on members to communicate to others in the group concerning "item x" increases monotonically with increase in the cohesiveness of the group.*

This proposition is precisely parallel to 1b, with  $C$  replacing  $R$ . Hence, it is translated by equations 1.2 and 1.5 with the conditions that  $U_C > 0$  and  $P_U > 0$ .

Hypothesis 3a: *The amount of change in opinion resulting from receiving a communication will increase as the pressure toward uniformity in the group increases.*

The amount of change in opinion—in the direction of greater or less uniformity—between times  $t_0$  and  $t_1$ , is expressed by the integral of  $dD/dt$  from  $t_0$  to  $t_1$ ,  $dD/dt$  being defined by equation 1.1. Let us assume, now, that  $f_p < 0$  and  $f_L < 0$ ; that is, the greater the pressure to communicate and the greater the receptivity to influence, the more rapid will be the change (decrease) in the discrepancy of opinion. We assume further, with Festinger, that  $L_U > 0$  in equation 1.3. We have already assumed that

$P_U > 0$ . It follows that  $\frac{\partial f}{\partial U} = f_L L_U$

+  $f_P P_U < 0$ , and hence that the rate of change of opinion toward uniformity will be the greater, the larger is  $U$ . The total change of opinion in the interval  $t_0$  to  $t_1$  will be the greater, the larger is  $dD/dt$  during this interval. Represent this total change in  $D$  by  $\Delta D$ , i.e.,

$$\Delta D = \int_{t_0}^{t_1} \frac{dD(t)}{dt} dt. \quad [1.6]$$

Then Festinger's hypothesis 3a is equivalent to the foregoing statement that  $\Delta D$  is the greater, the larger is  $U$  during the interval  $t_0$  to  $t_1$ .

Hypothesis 3b: *The amount of change in opinion resulting from receiving a communication will increase as the strength of the resultant force to remain in the group increases for the recipient.*

This hypothesis states that  $\Delta D$  is the greater, the larger is  $C$ . But  $C$  is related to  $U$ , via equation 1.5, with

the requirement that  $U_C > 0$ . And  $U$ , in turn, is related to  $L$  via equation 1.3, with  $L_U > 0$ . Then, since  $dD/dt$  is related in equation 1.1 to  $L$ , with  $\partial f/\partial L < 0$ , it follows that the integral of  $dD/dt$  for the interval  $t_0$  to  $t_1$  (or  $\Delta D$ ) will be greater, the larger is  $C$ . This indicates that Festinger's hypothesis 3b is not independent but follows from the earlier assumptions, namely those made in 1c and 3a.

We have now established an interpretation of Festinger's five hypotheses in terms of (a) four equations involving six variables (we have not yet made use of equation 1.4); and (b) a number of statements about the signs of the partial derivatives of the dependent variables with respect to the independent variables in these equations.<sup>4</sup> For convenient reference, let us restate the assumptions implied by the hypotheses about the signs of partial derivatives:

$$f_P < 0, \quad [1.1a] \quad f_L < 0, \quad [1.1b]$$

$$P_D > 0, \quad [1.2a] \quad P_U > 0, \quad [1.2b]$$

$$L_U > 0, \quad [1.3a]$$

$$U_C > 0, \quad [1.5a] \quad U_R > 0. \quad [1.5b]$$

Thus far we have said nothing about equation 1.4. This equation is not embodied in any of Festinger's more formal hypotheses, but is a translation of his statement that "People tend to locomote *into* [groups which share their opinions and attitudes] and *out of* groups which do not agree with them" (2, p. 273). Equation 1.4 states that the rate of change in co-

hesiveness of a group depends upon the discrepancy of opinion and the pressure toward uniformity. We postulate further that:

$$g_D < 0, \quad [1.4a] \quad g_U < 0. \quad [1.4b]$$

That is, a large discrepancy of opinion, for a given pressure toward uniformity, or a large pressure toward uniformity, for a given discrepancy in opinion, both bring about a rapid decrease in group cohesiveness. Note that we have also postulated that the change in cohesion is dependent upon the level of cohesion itself. Equation 1.4, or some alternative, is needed to make the dynamic system complete. We shall see that in some of the empirical studies, the mechanism of equation 1.4 is in fact involved; in others of the studies we need to assume instead that  $C$  is constant for the time interval of the experiment, that is,  $dC/dt = 0$ .

Interpretations have now been provided for all five equations, but nothing has been said about the signs of two of the partial derivatives,  $f_D$  in equation 1.1, and  $g_C$  in equation 1.4. Let us suppose a system governed by these five equations to be in equilibrium, so that  $dD/dt = 0$ , and  $dC/dt = 0$ . Then the values of the five dependent variables,  $D$ ,  $P$ ,  $L$ ,  $C$ , and  $U$  will depend only on the value of the single remaining independent variable  $R$ . Each value of  $R$  will determine a corresponding equilibrium position of the system. Now if  $P$  and  $L$  vary, as the system moves from one position of equilibrium to another, a determinate change in  $D$  must take place in order to satisfy equation 1.1. The direction of change in  $D$ , for increases in  $P$  and  $L$ , will depend on the signs of the two partial derivatives already assumed to be negative:  $f_P$  and  $f_L$ ; and upon the sign of  $f_D$ . In this situation, using

<sup>4</sup> Since the appearance or nonappearance of particular variables in particular equations and the signs of the partial derivatives in these equations do not depend upon the scales on which the variables are measured, our hypotheses satisfy the condition, earlier stated, that they should require only ordinal, and not cardinal, measurement of the variables.

the chain rule for differentiation,<sup>4</sup> we get:

$$f_P \delta P + f_L \delta L + f_D \delta D = 0, \quad [1.7]$$

where  $\delta P$ ,  $\delta L$ , and  $\delta D$  represent the changes in these variables in moving from one equilibrium position to a neighboring one. Applying the chain rule to equation 1.4 we find that:

$$g_D \delta D + g_U \delta U + g_C \delta C = 0. \quad [1.8]$$

On the basis of the interpretations we have given to the mechanisms, it is plausible to assume that if pressure to communicate ( $P$ ) and receptivity ( $L$ ) are large, then the discrepancy of opinion ( $D$ ) will be pushed down to a lower equilibrium level through the mechanism of equation 1.1 than if  $P$  and  $L$  are small. This is equivalent to saying that  $\delta D / \delta P = -(f_P / f_D) < 0$ , and  $\delta D / \delta L = -(f_L / f_D) < 0$ ; whence,

$$f_D < 0. \quad [1.1c]$$

Similarly, high levels of discrepancy of opinion ( $D$ ) and of pressure toward uniformity ( $U$ ), if maintained, may be assumed to drive cohesiveness ( $C$ ) to lower levels, through the mechanism of equation 1.4, than will low levels of  $D$  and  $U$ . It then follows by an argument similar to that just given that

$$g_C > 0. \quad [1.4c]$$

This completes the comparison of Festinger's propositions with our model. Note that in addition to the five equations, it was necessary to make explicit assumptions about the signs of eleven partial derivatives. By way of summary, we diagram in Fig. 1 the causal relations among the variables that are implied by the

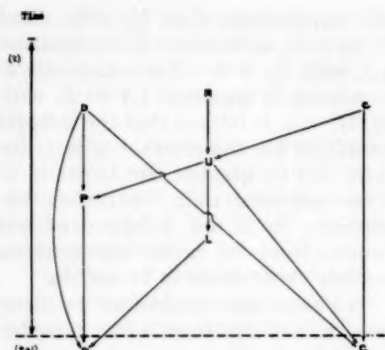


FIG. 1. Psychological mechanisms postulated in the model.

equations. For simplicity we assume changes in the variables to take place at discrete intervals in time rather than continuously. Thus  $D(t+1)$  is the value of  $D$  one time interval after  $t$ . By equation 1.1,  $D(t+1)$  is determined by  $D(t)$ ,  $P(t)$ , and  $L(t)$ . By equation 1.2,  $P(t)$  is determined by  $D(t)$  and  $U(t)$ ; by equation 1.3,  $L(t)$  is determined by  $U(t)$ ; by equation 1.4,  $C(t+1)$  is determined by  $C(t)$ ,  $D(t)$ , and  $U(t)$ ; and by equation 1.5,  $U(t)$  is determined by  $R$  and  $C(t)$ .

## 2. EXAMINATION OF THE EMPIRICAL STUDIES

Festinger draws upon evidence obtained in a number of experiments and a field study for confirmation of the hypotheses. In this section we shall re-examine the evidence from three of the studies in terms of the aggregative model that has been formulated. Our purposes are twofold: (a) We want to check the extent to which the empirical data support or contradict our reformulation of Festinger's system; and (b) we want to know whether all of the eleven "derivative" hypotheses have been tested

<sup>4</sup> See the chapter on partial differentiation in any standard calculus, e.g., Granville, *Elements of the Differential and Integral Calculus*, (rev. ed.), 1929, p. 419; or Osgood, *Advanced Calculus*, 1935, pp. 112-119.

—and if not, just which ones remain to be tested in future experimental work.

*Back's Influence Experiment.* Back (1) performed an experiment with teams of two subjects each. Each team member was instructed to write an interpretation of pictures he had seen alone before discussion with his teammate, and again after discussion. Each subject believed his pictures were identical with those seen by his teammate, but they were in fact somewhat different.

Opinion change in a team was measured by a content analysis of the similarities and differences in the interpretations of teammates. In this way, a measure could have been obtained of  $D_0$ , the discrepancy at the beginning of the trial, and  $D_T$  the discrepancy at the end of the trial. Back did not, in fact, measure  $D_0$  and  $D_T$ . Instead, he noticed the number of changes that took place between the initial and final interpretations in the direction of the partner's interpretation (1, Tables 4 and 5). The number of such changes may be taken as a measure of the *decrease* in difference in opinion, i.e.,  $D_0 - D_T$ . Since the times of all trials were short and equal,  $D_0 - D_T$  will be approximately proportional to  $dD/dt$  at time  $t_0$ . We shall accordingly represent it by the symbol  $\Delta D_0$ .

No measurement was made that can be regarded unequivocally as a direct measure of pressure to communicate ( $P$ ), receptivity ( $L$ ), or pressure toward uniformity ( $U$ ). This is hardly surprising, since all these variables refer to "states" of the subject, lie entirely inside his skin, and hence can be observed only indirectly through behaviors they produce. Back made three sets of observations intended to serve as indices of these latent variables. The first measure was a rating of the team discussion by observers as *active* or *with-*

*drawing*. An active pattern will be interpreted as evidence of high  $P$ , a withdrawing pattern as evidence of low  $P$ . The second measure was the report of subjects as to whether they felt, in the discussion situation, some or no pressure from their partners to change their interpretations. Reported pressure will be interpreted as high  $U$ , lack of pressure as low  $U$ . Third, subjects were also asked to report whether they had been receptive to influence by the partner. These reports will be regarded as measures of  $L$ .

No direct measurement was made of cohesiveness or relevance. The instructions given to team members at the beginning of the trials were intended to produce high cohesiveness in half the teams and low cohesiveness in the others. The instructions, as interpreted by Back, are given as indirect measures of  $C_0$ . That certain instructions to the subjects will produce high or low cohesiveness is based only on "common sense" and introspective interpretation of the psychological impact of the instructions. Hence, it would have been better if  $C$  also had been measured directly.

It is not clear whether the intergroup differences produced by the instructions should be regarded only as differences in  $C_0$ , or whether they should be regarded as differences in  $R_0$  as well. In three different sets of experimental groups, Back attempted to employ three different bases for inducing high or low cohesiveness: personal attraction to the team partner, reward for group performance, and the prestige of the group. Back argues that pressure toward uniformity arises from two sources: the function of the group as a reference group in determining social reality (which depends on *cohesiveness*), and the function of the group as a means

toward reaching a personal goal (which operates through the *relevance* of uniformity of opinion to goal achievement). It is reasonable, therefore, to interpret the first and third of the motivations in Back's experiment as cohesiveness-producing motivations; but to interpret the second—reward for performance—as a relevance-producing motivation. Hence, we shall assume that the experimental instructions produce differences both in  $C_0$  and in  $R_0$  for all three sets of groups. In the present interpretations of the model this distinction is not vital, for  $U_C$  and  $U_R$  are both positive, and hence act upon  $U$  in equation 1.5 in the same direction. A clarification of the distinction would appear important, however, to further development and testing of the theoretical scheme, if any operational significance is to be attached to the asserted difference between these two variables.

It is implicitly assumed in the experimental design involving team discussions of about ten minutes that the effect of the instructions upon cohesiveness and relevance persisted for the duration of the experiment. If this is correct we can eliminate equation 1.4 from the system, and assume that  $C$ , like  $R$ , in equation 1.5 is a parameter, constant for the duration of the experiment with any one group. This amounts to an interpretation of this experiment in terms of a "short-run" model in which the mechanisms represented by the remaining four equations were operating, but in which the system did not have time to settle to a final equilibrium. We simply ignore the "feedback" effect of  $dD/dt$  on  $D$ . Then we may regard the equations as four relations that determine the values of the dependent variables  $\Delta D_0$ ,  $P_0$ ,  $L_0$ , and  $U_0$  as functions of the independent variables (or "parameters")  $D_0$ ,  $C_0$ , and  $R_0$ . Finally,

since  $D_0$  is assumed to be the same for all groups (the same sets of pictures were shown to all groups), this variable may be ignored in analyzing the intergroup differences.

What predictions can we make from the model of the Back experiment so interpreted? If we employ symbols like  $\delta P$ , again, to designate intergroup differences in the initial values of the dependent variables as functions of intergroup differences in the independent variables, we can deduce the following from our previous equations by differentiating them, using the chain rule:

$$\delta U_0 = U_C \delta C + U_R \delta R, \quad \text{(from equation 1.5), [2.1]}$$

$$\delta L_0 = L_U \delta U, \quad \text{(from equation 1.3), [2.2]}$$

$$\delta P_0 = P_U \delta U, \quad \text{(from equation 1.2), [2.3]}$$

$$\delta \Delta D_0 = f_P \delta P + f_L \delta L, \quad \text{(from equation 1.1). [2.4]}$$

From these relations, together with the previous assumptions as to the signs of partial derivatives, the following hypotheses can be derived by algebraic means, taking  $C$  and  $R$  as independent variables:

$$\delta U / \delta C = U_C > 0, \quad [2.1a]$$

$$\delta U / \delta R = U_R > 0, \quad [2.1b]$$

$$\delta L / \delta C = L_U U_C > 0, \quad [2.2a]$$

$$\delta L / \delta R = L_U U_R > 0, \quad [2.2b]$$

$$\delta P / \delta C = P_U U_C > 0, \quad [2.3a]$$

$$\delta P / \delta R = P_U U_R > 0, \quad [2.3b]$$

$$\delta \Delta D / \delta C = (f_P P_U + f_L L_U) U_C < 0, \quad [2.4a]$$

$$\delta \Delta D / \delta R = (f_P P_U + f_L L_U) U_R < 0. \quad [2.4b]$$

Let us now check the extent to which Back's empirical findings con-



firm these predictions. The fact that persons in the high cohesive groups tried to influence ( $P$ ) their partners more actively (chi square significant at .02 level) than did individuals in the low cohesive groups, who tended to withdraw (1, p. 15), may be taken as confirmation of equations 2.3a and 2.3b. His finding that "less than half of the members of the low cohesive group reported that they felt some pressure ( $U$ ), while more than two thirds of the members of the high cohesive group did so" (1 p. 16) (again significant at the .02 level), does not contradict equations 2.1a and 2.1b. Although Back says "Self-ratings on resistance [the inverse of  $L$ ] . . . show a slight decrease" (1, p. 16) in level in the high cohesive groups, he reports the difference is not statistically significant. Thus, there is only weak confirmation of equations 2.2a or 2.2b.

Table 4 in Back's report (1) provides confirmation for equation 2.4a,  $\delta\Delta D/\delta C < 0$ ; and equation 2.4b,  $\delta\Delta D/\delta R < 0$ . These significant findings are consistent with the assumptions of the original model but *do not*, it should be noted, *verify* all the individual assumptions about the signs of partial derivatives. The lack of confirmation, at a significant level, of equations 2.2a and 2.2b is disturbing, since  $L_U U_C$  or  $L_U U_R$ , or both, appear in all the other hypotheses, too. Since  $\partial L/\partial C$  and  $\partial L/\partial R$  are found empirically not to be significantly different from zero, either  $L_U$  or both  $U_C$  and  $U_R$  must be close to zero. But inasmuch as confirmation of equations 2.1a and 2.1b indicates that  $U_C \neq 0$ ,  $L_U$  must be close to zero; such a conclusion is not contradicted by our confirmation of equations 2.4a and 2.4b, for the  $f_L L_U$  terms might be zero without changing the signs of  $\delta\Delta D/\delta C$  or  $\delta\Delta D/\delta R$ .

In summary, we may say that Back's experiment constitutes a test of some short-run properties of the present mathematical model. The findings of the experiment verified some, but not all, of the assumptions regarding the signs of partial derivatives, and strongly contradicted none of the assumptions. If the experiment were to be repeated, its power to test the model could be increased by introducing additional procedures for measuring certain of the variables, such as  $R$ ,  $C_0$ , and  $C_T$ .

*The Festinger-Thibaut Experiment on Interpersonal Communication.* This experiment (4) involved variables referring to individual members of a group, as well as variables defined as group averages. The present discussion is limited to those findings of the experiment that can be stated in terms of aggregates.

A problem was given to members of a discussion group, and they were asked to record their solutions before and after discussion. The standard deviations of the opinions in each group at the beginning of the twenty-minute discussion and at the end are taken as measurements of the variable  $D$ —specifically,  $D_0$  and  $D_T$ . The several experimental groups were initially given different sets of instructions. The instructions that aimed at inducing "homogeneity" stressed the similarity of group members, and can be interpreted as cohesiveness-producing variables. The instructions aimed at producing "pressure toward uniformity" stated that the group should arrive at agreement on opinion or at the "correct" opinion. In Festinger's scheme, this variable may be translated as *relevance*. We shall treat the homogeneity-heterogeneity instructions as determining  $C_0$ , and the other instructions as determining  $R_0$ .

The appropriate model for this experiment would appear to be the same as for the Back experiment. The experimental findings can be expressed (4, p. 99, Fig. 2) as  $\delta\Delta D/\delta C < 0$  and  $\delta\Delta D/\delta R < 0$ . Thus we see that the findings in this experiment exactly parallel one of the findings in the Back experiment.

The need for further clarification of the variables  $C$  and  $R$  is evidenced by the fact that Festinger cites Back's experiment as evidence for his hypothesis 3b, and the Festinger-Thibaut study as evidence for his hypothesis 3a, while we have concluded that there is no difference in the findings regarding  $\Delta D$  in the two experiments. The reason for this difference is that Festinger treats the instructions in the Back experiment as determining  $C$  and instructions in the Festinger-Thibaut experiment as determining  $U$ , while we have interpreted these instructions as determining  $C$  and  $R$  in both experiments.

*The Housing Study.* Unlike the two experiments already discussed, the housing study (3) was a field study and not an experiment. This has two consequences. First, the field situation reflects the working of all the mechanisms actually present. Individual variables cannot be made "independent" through experimental control and randomization, as they can in the laboratory. Second, the relevant time span during which the mechanisms operate is much longer in the field situation than in the laboratory. In a relatively stable field situation of this sort we can expect to observe the variables only in the neighborhood of the equilibrium position or positions of the system.

In the field study, a correlation of .74 was found between (a) the cohesiveness of groups in a housing project, and (b) the effectiveness with which a group standard relevant to

the functioning of the groups was maintained (3, p. 12, Table 16). Festinger treats these findings as parallel to the findings in Back's work in confirmation of hypothesis 3b.

In interpreting the earlier experiments, because of the short time period involved, the feedback described by equations 1.1 and 1.4 could be ignored. Moreover, the variable  $D_0$  was assumed to be the same for all groups at the outset of the experiment. In the field study, there is no reason to suppose that we can ignore the change of  $D$  and  $C$  through time, as determined by equations 1.1 and 1.4. Furthermore, the variables that are correlated are  $D_T$  with  $C_T$ , and not  $D_0$  with  $C_0$  and  $R_0$ , for the measurements were made after the residents of the housing project had been residing there and interacting for a considerable period (up to 15 months).

These considerations suggest that the appropriate model for representing the field study is the complete model of equations 1.1 through 1.5, together with the corresponding inequalities. If this is so, then the short-run assumptions that permitted us to apply the method of comparative statics in the two experiments are no longer applicable. Given the initial conditions, the time path of the behavior of the group will be determined by equations 1.1 through 1.5, and two groups with the same initial positions will have the same paths. If we assume that the initial values of at least some variables were different for the various groups, we can derive a plausible interpretation of the field study, and can show also that the field results prove something quite different from (but not inconsistent with) Back's experiment—contrary to Festinger's interpretation of the two sets of data as supporting the same proposition.

Using equations 1.2, 1.3, and 1.5 to solve for  $P$ ,  $L$ , and  $U$ , respectively,

the system can be rewritten in terms of two different equations in  $C$  and  $D$ :

$$\frac{dD}{dt} = f\{P[D, U(C)], L[U(C)], D\}, \quad [2.6]$$

$$\frac{dC}{dt} = g\{D, U(C), C\}. \quad [2.7]$$

Now for a system obeying these equations and starting off from some initial position  $[D_0, C_0]$  we can represent its path by a curve in the  $D$ - $C$  plane. Each point on the curve  $[D(t), C(t)]$  will represent the position of the system at some time,  $t$ . What can we say in general about the various paths corresponding to different initial conditions?<sup>6</sup>

Consider the points for which  $dD/dt = f = 0$ . These lie on a curve on the  $D$ - $C$  plane. Moving along this curve, the requirement that  $f = 0$  gives us the following equation for the ratio between the rate of change of  $C$ , i.e.,  $\delta C$ , and the rate of change of  $D$ ,  $\delta D$ :

$$f_P\{P_D\delta D + P_U U_C \delta C\} + f_L L_U U_C \delta C + f_D \delta D = 0. \quad [2.8]$$

This expression is obtained by differentiating equation 2.7, using the chain rule. Then we have for the slope of this curve:

$$\rho = \left[ \frac{\delta C}{\delta D} \right]_{dD/dt=0} = - \frac{(f_P P_D + f_D)}{U_C (f_P P_U + f_L L_U)} < 0. \quad [2.9]$$

Similarly, for the curve on which  $dC/dt = g = 0$ , we obtain:

$$\sigma = \left[ \frac{\delta C}{\delta D} \right]_{dC/dt=0} = - \frac{g_D}{g_U U_C + g_C} < 0. \quad [2.10]$$

<sup>6</sup> For the methods applied here, see Lester R. Ford, *Differential Equations*, pp. 9-12; and A. A. Andronow and C. E. Chaikin, *Theory of Oscillations*, 1949, pp. 8-12, 182-193, 203-8.

By using our assumptions about the signs of these partial derivatives already made above, it can be shown that the slopes of both these curves are negative in the  $D$ - $C$  plane.

Now there are grounds of plausibility for making assumptions which enable us to say that these curves have a particular shape—specifically, that  $\sigma$  approaches zero for very large and very small values of  $C$ , and that  $1/\rho$  approaches zero for very large and very small values of  $D$ . The argument is as follows: Equation 2.7 describes a mechanism whereby cohesiveness adjusts to discrepancy of opinion. It is plausible to suppose that this mechanism is subject to saturation—that when  $C$  reaches very high levels it will not be driven much higher by further decreases in  $D$ ; and that when  $C$  reaches very low levels it will not be driven much lower by further increases in  $D$ . A similar saturation assumption is plausible for the mechanism of equation 2.6 which determines the equilibrium level of  $D$  as a function of  $C$ .<sup>7</sup>

If the two saturation hypotheses hold, then the curves  $f = 0$  and  $g = 0$  must have one of three possible configurations (Fig. 2). In cases I and II we have a single point of equilibrium—a point for which simultaneously  $f = dD/dt = 0$ , and  $g = dC/dt = 0$ . In case III we have three such points of equilibrium. An analysis by standard methods (omitted here) shows that certain conditions must be satisfied if the equilibrium position is

<sup>7</sup> These two saturation hypotheses each imply cardinal measurement of  $C$  and  $D$ . The conclusions we shall draw from the two of them together, with respect to the existence and location of stable and unstable equilibrium points, depend, however, on only ordinal measurement. It would be desirable to restate the saturation hypotheses—or that part of them we need—so as to remove the cardinality assumptions. This must be possible, but we have not yet been able to do it.

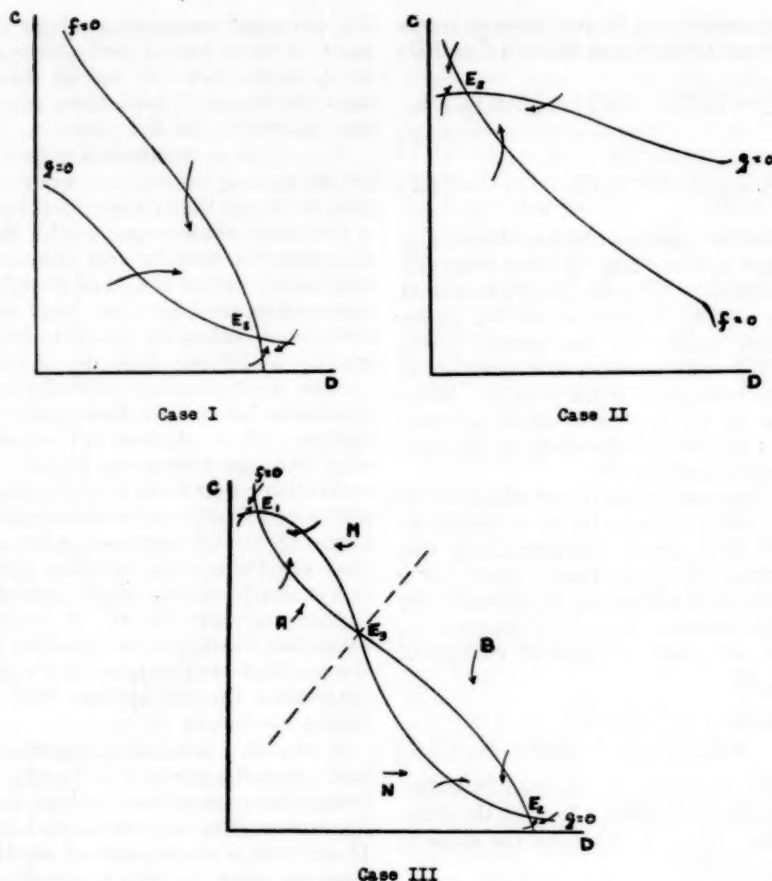


FIG. 2. Single and multiple equilibrium.

to be dynamically stable (so that if the system is disturbed slightly from equilibrium, it will tend to move back toward the equilibrium position). The stability condition is:

$$\sigma/\rho < 1. \quad [2.11]$$

We observe from Fig. 2 that equation 2.11 is satisfied for the equilibrium points ( $E_1$ ) in case I and case II, and for the two extreme equilibrium points ( $E_1$  and  $E_2$ ) in case III.

In the housing study tenants were assigned to particular courts in the housing project, virtually at random. The initial cohesiveness ("tendency to associate") of residents of a court might depend largely on the opportunities people found to meet others inside and outside the project. The initial discrepancy of opinion in a court with regard to a tenant's organization might be regarded as a chance variable depending on the past experi-

ences of the tenants with such neighborhood activities. Quite by chance, some courts would have a higher initial  $D$  or  $C$  than others.

Now suppose that two groups (A and B) initially had the same cohesiveness within their courts, but that there was much less initial divergence of opinions with regard to the desirability of a tenants' organization in one (A) than in the other (B), as is illustrated in case III of Fig. 3. If the  $D_0$  of a particular court is low, as in A, the cohesiveness of the tenants will increase, which in turn will cause them to accommodate their opinions to each others', further decreasing  $D$ . If the  $D_0$  of a court is high, as in B, the cohesiveness of the tenants will decrease, which will promote further divergence of opinion. All these consequences follow from the postulates of the mathematical model. Hence, when the system reaches equilibrium we should expect to find some courts with high  $C$  and low  $D$ , and some with low  $C$  and high  $D$ , giving a negative correlation between  $C$  and  $D$ . Further, as the process approaches equilibrium, one would expect a clustering of points (representing the courts) around the two stable equilibria,  $E_1$  and  $E_2$ . A plot of the data from the Festinger, Schachter, and Back study,

as presented in Fig. 3, case III, reveals just such a clustering, giving empirical confirmation of our postulation that the feedback process has been in operation.

This interpretation of the field work permits a prediction of the observed correlation from the postulates of the mathematical model. The predicted correlation depends, however, on a larger set of hypotheses than those used in the interpretation of the Back and the Festinger-Thibaut experiments. To account for the findings, both feedbacks provided in equations 1.1 and 1.4 were needed, and the two saturation assumptions were added. Festinger's original interpretation of the laboratory and field results as supporting hypothesis 3b was hardly accurate. Our formalization of the hypothesis shows its complexity, and indicates that the Back experiment supports the short-run static model, while the Festinger, Schachter, and Back data support the enlarged dynamic model.

Note that only case III of Fig. 2 predicts a negative correlation; cases I and II predict that the points in the  $C$ - $D$  plane should cluster around  $E$ , thus yielding a zero correlation. Yet data supporting any one of the three cases would be consonant with the

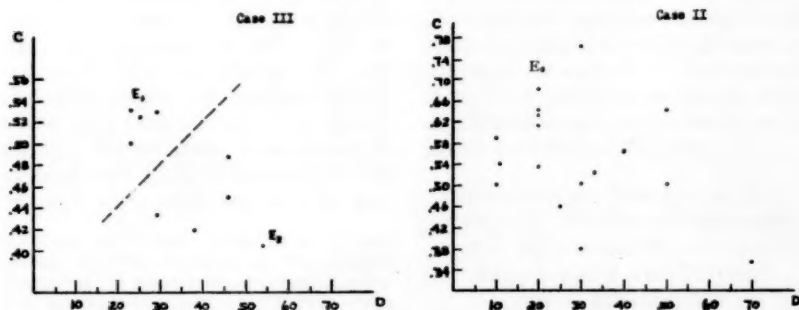


FIG. 3. Empirical tests of the equilibrium cases. In case III, data are from reference 3, p. 92, Table 16; in case II, data are from reference 3, p. 93, Table 17.



hypotheses used in developing the model. Which of the three cases will hold depends upon the equilibrium equations (the relative positions of the two equilibrium curves on the  $D$ - $C$  plane). If we plot the data obtained in the second housing project (3, p. 93, Table 17), we find that these data seem to correspond to case II, presented in the "Case II" graph in Fig. 3. According to our arguments, Festinger, Schachter, and Back incorrectly interpret their zero correlation as indicating no feedback had yet occurred in the few months Westgate West had been in operation. The clustering of points at  $E_s$  indicates that the dynamic model is applicable, and that some groups in this cluster of points are close to equilibrium. The zero correlation between  $C_T$  and  $D_T$  actually confirms the existence of feedback.

#### SUMMARY

In this paper we have undertaken to carry further the development of a set of hypotheses about pressures toward uniformity in groups into a more integrated, less redundant system. We have constructed explicit postulates about the intervening mechanisms to provide linkages among variables, such as "Relevance"

and "Pressure to Communicate." Although the model covers static situations in which there is no feedback, it also postulates dynamic mechanisms by which, for example, cohesion at one time influences the cohesion of the same group at a later time. In the present paper, all the variables considered were averages of the behaviors of all members of a group.

A number of deductions were obtained from the system. Some of these were verified by bringing field and experimental data to bear. The model led us to examine correlational data for bimodality characteristics, indicating the existence of two stable equilibrium points when groups experience uniformity.

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## THE CONCEPT OF EFFICIENCY IN PSYCHOLOGICAL HEALTH AND IN PSYCHOPATHOLOGY<sup>1</sup>

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The central problem of this paper is to formulate a descriptive concept of psychological health and psychopathology. We shall be concerned more with the adequacy of the conception for the laboratory situation than for its immediate applicability to clinical formulations or to psychotherapy.

By way of introduction, it might be useful to point to certain differences in the implications of the terms "health" and "normality." It is true, of course, that the two are often used interchangeably, but this leads to confusion in conception and is a reflection of the multiple meanings, sometimes mutually exclusive, attached to the terms (cf. 9). We may distinguish between them by using "normal" only in relation to the normal curve of distribution. Abnormality, then, represents deviation from some norm. It does not, in itself, convey information concerning the adequacy or appropriateness of behavior. Health, on the other hand, implies precisely such information; it does not necessarily convey information concerning norms or frequency of occurrence of some phenomenon. Understood in this way, the discussion to follow will be concerned with the problem of psychological health and psychopathology rather than with normality and abnormality. Nevertheless, experimentation utilizing both kinds of conceptions will be cited, since there has been no gen-

eral agreement on a standardized usage. It should be noted that to eschew a wholly relativistic notion of health in terms of normality does not mean that the criteria must necessarily be of the absolutistic variety. The object is to formulate a dimension in which any two behavior patterns can be compared as to the degree of health indicated. The behavior need be referred neither to an absolute, *a priori*, criterion nor to some empirical norm.

Further, it should be seen that the formulation of such a dimension is not necessarily related to the social definition of psychological health. This may vary from society to society and from time to time, presumably depending upon social conditions, degree of knowledge, availability of treatment facilities, etc. However, what a particular society says is healthy at a given time is not necessarily central to a scientific formulation of a dimension of psychological health. A particular society may believe malaria to be a sign of health, but the definition of physical health need not be concerned with such an opinion. Certainly such opinions can become important questions for many kinds of research, as for example, in investigations of attitudes, but they are not of central significance in the formulation of an objective definition of the field.

### PSYCHOLOGICAL HEALTH AS EFFICIENCY IN MEETING ENVIRONMENTAL REQUIREMENTS; PSYCHO-PHYSIOLOGICAL AND PSYCHOMOTOR EXPERIMENTS

Individual cases of psychopathology as seen in the clinic present the investi-

<sup>1</sup>Based on a paper presented at a symposium on "The Meaning of Psychological Health" at the Eastern Psychological Association meetings in Boston, April 1953. The writer is indebted to Mr. Thomas E. Shipley, Jr., for aid in the formulation, and to several colleagues for critical comments.

gator with such a multiplicity of different problems that it does not appear likely that they can all be subsumed under a single rubric with respect to their origin. Nevertheless, they are recognized as having in common some form of psychopathology. Although various classificatory systems have been offered which attempt to categorize such individuals into classes differing in kind, there remains a basic assumption that they can also be ordered with respect to the degree of psychopathology shown; i.e., individual cases are recognized as being more or less disturbed.

What are the criteria of disturbance? Many have been proposed. In general, they can be grouped into two classes, which are not necessarily mutually exclusive: (a) those emphasizing subjective feelings, personal discomfort, persistent feelings of tension, etc., and (b) those emphasizing "appropriateness" or "adequacy" of objectively measurable behavior. For the most part, the textbooks try to combine these (e.g., 4). Without entering into the endless controversy over the possibility of the scientific study of subjective feelings, the present discussion will be confined to a consideration of objectively measurable behavior.

On the basis of experimental data, the argument will be developed that the continuum of psychological health and psychopathology can be conceptualized in terms of the degree of efficiency in meeting environmental requirements. The definition of efficiency and environmental requirements is one of the tasks of this section, and will be discussed presently. For the moment, it is well to indicate that inefficiency may be focalized at the perceptual, cognitive, feeling, or action levels, and the seriousness of the consequences may be a function of the particular focus. The essential point is, however, that without some

inefficiency no psychopathology would be recognized.

The formulation proposed here has as its principal point of departure those definitions of psychological health emphasizing appropriateness and adequacy of behavior. Aside from the more specific operational analysis to be given for the present terminology, the term efficiency is preferred here to such terms as appropriateness or adequacy because the latter usually involve *a priori* value judgments, which would make an objective definition of psychological health impossible. Moreover, efficiency immediately implies something quantifiable, whereas appropriateness and adequacy are usually considered in qualitative terms. Apart from this, all three terms, as used in this paper, have similar connotations.

Efficiency is a meaningful parameter only when the most important aspects of the task to be completed can be specified. Thus, with respect to behavior in "everyday life," the difficulties encountered in the use of such concepts as appropriateness are not surmounted by the use of the term efficiency. For the essential stumbling block remains: our inability to specify objectively what behavior is required. This is neither surprising nor crucial. The everyday situation is experimentally uncontrollable, and the testing of scientific hypotheses requires controlled conditions. A broken bone may not be diagnosable in everyday life. The fact that an X ray must be taken under controlled conditions makes it no less relevant to general anatomical integrity. Similarly, efficiency may not be measurable in everyday life, but this does not affect its relevance to the problem of psychological health if a relationship can be shown to hold under experimentally controlled conditions. With this argument in mind, we can turn to a consideration of the methods of measure-

ment of efficiency in the psychological laboratory, and their relationship to the continuum of psychopathology.

The laboratory situation provides a ready method for specifying the task requirements. These consist of the experimenter's instructions and the relation of these to the stimulating field. If the subjects are motivated to cooperate with the experimenter, the task requirements can be held relatively constant, but their structure, i.e., their "requiredness-qualities" must be known. Thus, the problem for controlled experimentation should be centered on finding a method for measuring efficiency and the clear specification of task requirements.

In psychological experiments, efficiency has often been equated with productivity. It should be apparent immediately that such a measure cannot be very useful in relation to psychological health and psychopathology, for it takes no account of the comparative effort exerted to accomplish a given task. It is a common observation that neurotics will often achieve some end, but at a terrible price to themselves, sometimes to the point of breakdown. Productivity, as measured by speed or complexity of performance, is indeed an important dimension of performance, but it is not, by itself, an index of efficiency. The latter requires a more complex analysis.

In inanimate machines, efficiency is a function of the ratio of output to input, and the latter can be controlled while the former is measured. In animals, however, input, in the same sense as in a machine, is *an unknown quantity in relation to any given task*. Only the direction of energy expenditure can be observed. In a previous paper (24), it was suggested that, with respect to any given task requirements, at least two components of the energy expended can be distinguished: (a) focused behavior (*F*), energy expended directly on the

task, and (b) diffuse behavior (*D*), energy expended in irrelevant directions. The most common method of measurement consists in recording simultaneous indices of tension, such as muscle action potentials, from a part of the body immediately involved in work and a part of the body not thus involved. A mirror-tracing experiment by Telford and Swenson (20) may serve as an illustration. They recorded pressures exerted on bulbs by both hands while one was occupied with the tracing. As performance improved, they found a decrease in pressure in the unused hand and an increase in the used hand. Such results support the notion that a comparison of simultaneous *D* and *F* activity may be a valid index of efficiency.

In the paper previously cited (24), evidence was adduced for the hypothesis that individuals with psychopathology are characterized by a preponderance of *D* activity, as compared to *F*. Other findings point in the same direction, although, as will be seen, an additional factor probably needs to be introduced because of the inadequacy of our present analyses of tasks and of our measuring techniques. Luria (10) was concerned with the relationship between psychic conflicts and motor as well as associative processes. He used the word association technique, and his subjects were instructed to press down on a tambour with their right hand as soon as they gave a response word to the stimulus. Measurements were made of the movement of the left hand as well as of the right hand. Luria found that some form of motor disorganization and verbal blocking accompanied psychological disturbance, whether induced or existing in its natural state. Similar findings have been reported by Duffy (6) and Arnold (1).

An analysis of Luria's task might be useful here since much of the current work in this area utilizes his technique

as a point of departure. In terms of *D* and *F* activity, it would appear that the performance of the instructed right-hand movement in close coordination with the verbalization of the response word would constitute *F* activity; other movements of the right hand and all movements of the left hand would constitute *D* activity. This analysis leaves something to be desired, however. For example, there is no meaningful way of quantifying *F* activity. The intensity of right-hand pressure might represent either *D* or *F* activity. Pushing down hard on the tambour with the right hand could be a reflection of intense disturbance which might not be seen in any other aspect of motor activity measured. The essential difficulty lies in the fact that the activity called for is not an integral part of the whole task, the central requirement of which is associating a meaningful word to the stimulus as rapidly as possible. Much cognitive activity occurs in this process, and there is no way of telling which part of it is *D* and which *F*. The required movement of the right hand has been appended arbitrarily by the experimenter to the central need for a word association; i.e., the structure of the situation demands intrinsically a verbal response. The motor activity requested is essentially ancillary. That it is an arbitrary appendage to the central structure of the task can be seen if it is recognized that it can just as easily be included in a host of other situations. This makes Luria's findings all the more interesting, since, despite the lack of inherent relationships of the movements to the task, psychic conflict is still reflected in *D* activity.

The same critique can be applied to a recent series of rather ingenious experiments by Malmo *et al.*, only two of which will be discussed here (11, 12). In one experiment (11), these investigators utilized the Luria technique

with electronic measurement, with four groups of subjects: controls, psychoneurotics, acute psychotics, and chronic schizophrenics. The degree of motor disorganization found in the various groups is just what might have been expected on the basis of clinical experience. The chronic schizophrenics were most disorganized, the acute psychotics were next, the psychoneurotics next, and the controls were significantly different from all other groups. At the same time, there were no significant differences between the controls, psychoneurotics, and acute psychotics in productivity, as measured by the number of accurate discriminations of sizes of circles. Only the chronic schizophrenics were significantly different from the rest of the subjects in this respect, probably as a result of inadequate attention.

In another experiment by these investigators (12), the question of the relevance of the activity measured to the task requirements is raised even more acutely. With the same groups of subjects, they measured the changes in muscle action potentials in the right arm and neck in response to various intensities of heat stimulation to the forehead. The subjects were instructed to press down on a key as soon as they felt that the stimulus was about to become painful. It should be apparent that this situation allows for no objective specification of the task requirements. Many different kinds of evaluations of the situation by the subject are plausible, and these might well influence the nature of their responses. Nevertheless, the results are of interest here because they suggest the need for inclusion of some measure of productivity in the quantification of efficiency in the context of this discussion. If we assume, for the sake of further evaluation, that right-hand tension in this experiment represents *F* activity and that



neck tension represents  $D$  activity, the findings show no difference in efficiency between chronic schizophrenics and controls. This is obviously a function of the fact that the former showed very little change in muscle tension anywhere; i.e., the chronic schizophrenics were simply unreactive to the stimulation. Qualitatively, this might be said to be inappropriate behavior. Nevertheless, if the assumptions concerning  $D$  and  $F$  activity in this experiment are tenable, the proposed *quantification* would break down in relation to a continuum of psychopathology if Malmo's findings concerning chronic schizophrenics are confirmed. By taking into account the productivity ( $P$ ) of the individual, how he *actually affects his environment*, this situation can be remedied. It is known, as is shown in the first experiment cited (11), that chronic schizophrenics are underproductive. Thus, when they are not reactive, their failure to produce, if used as a multiplicative factor, would produce a low efficiency ( $E$ ) rating. Thus, a general equation for efficiency in motor activity might be written:  $E = f(F/D, P)$ . Of course, the specification of the exact nature of the function must await empirical findings from experiments oriented to this problem.

A final comment about the possibilities of measuring ostensive  $D$  and  $F$  activity in clearly defined situations seems necessary in view of the above criticism of previous experiments. What is required is that the activity be an intrinsic aspect of the total structure of the task. In addition, unless  $D$  and  $F$  activity can be clearly defined in the particular situation, complex cognitive activity will have to be circumvented, at least in psychomotor experiments;

for it is entirely unclear which motor behavior is relevant to which cognitive operation. These prerequisites to the measurement of psychomotor or psychophysiological efficiency may be met by utilizing relatively simple situations, such as simple reaction time. They can also be met in more complex situations by appropriate analysis and measurement, as is seen in an old experiment by Morgan (13). He was interested in the effect of noise on the work output of typists. The subjects were required to decode a letter which the experimenter showed them and press the appropriate key on a keyboard. Measurement was made of the pressure on the key, as well as of total work output under quiet and noisy conditions. The results are interesting and point up the previous analysis of the difficulty of specifying the  $F$  activity in Luria's experiments. The effect of noise on work output was insignificant. As a matter of fact, after an initial decrease, output increased slightly as adaptation occurred. At the same time, there was an increase in pressure exerted on the keys under conditions of noise. This result also points up the probable need for the inclusion of a productivity measure in the rating of efficiency. For if increase in pressure were relatively uniform among the subjects, then it would still be possible to rate them as to their productivity, which would certainly reflect, all other things being equal, the efficiency with which they adapted to the noise situation.

To summarize this section, it has been proposed that psychological health and psychopathology be conceived as a continuum and defined in terms of the efficiency with which environmental requirements are met. It was pointed out that for the present this definition can be useful only in a relatively narrow laboratory situation because of the difficulties involved in the specification

of objective requirements in the social sphere. Consideration of several experiments indicated that efficiency is a function of the ratio of focused to diffuse activity and of productivity, and that this is related to degree of psychopathology.

Thus far we have dealt with relatively simple psychomotor experiments. Attention will now be focused on efficiency in other laboratory situations.

#### EFFICIENCY IN LEARNING AS RELATED TO PSYCHOPATHOLOGY

Whatever may be the validity of efficiency in psychomotor activity as an index of psychopathology, it is, at best, a superficial descriptive parameter, another method of measurement. If the present proposal is to have any general significance, it will be necessary to explore its applicability to some of the more crucial fields of modern psychology. For psychopathology, these include, at least, learning and motivation, which will occupy our attention in this and the following section.

The relationship of anxiety and conditioning has occupied the attention of numerous investigators recently. It appears to be a most stable finding that in a classical conditioning situation the rate of conditioning is greater in anxious than in nonanxious individuals (3, 15, 16, 17, 18, 21, 22). The opposite findings are reported in serial learning (7, 8, 19), but apparently the nature of the task is an important variable which can affect the results markedly (14). The measures of anxiety differ from study to study, and it is still an open question whether the same independent variable is being used in each case, as Child (5) has pointed out. On the other hand, it is probable that the rate of conditioning in a classical situation is related to degree of psychopathology. Welch and Kubis (21, 22) found a significant difference between anxiety patients and

normals in rate of conditioning of the galvanic skin response (GSR). Spence and Taylor (17) found a significant difference between psychotics and neurotics or normals in percentage of conditioned eyeblink responses. They report no significant difference between neurotics and normals. It is thus questionable whether anxiety, clinically identified, is a necessary condition for the reported phenomena in this area, for it is by no means clear that psychotics are always characterized by anxiety. Spence and Taylor do not state the clinical characteristics of their group. It must be noted, however, that, in the clinical situation, psychosis is often regarded as a retreat from realistic problems that give rise to anxiety.<sup>2</sup>

If these data are to be analyzed in terms of the degree of efficiency shown by the subjects, a thorough examination of the task requirements must be made. For this purpose the experiment by Welch and Kubis (22) is particularly well suited. They utilized two groups of subjects, 22 normals and 24 patients who presented a clinical picture of anxiety. They conditioned the galvanic skin response to the syllable "kax" which was one of 54 nonsense syllables presented to the subjects in random order. The unconditioned stimulus was a buzzer which was sounded on alternate presentations of "kax." The results showed that the anxiety patients conditioned about three times as quickly as the normals and extinguished about twice as slowly; i.e., the anxiety patients took one-third as many trials to condition as the normals and twice as many trials as the normals to extin-

<sup>2</sup> The writer is aware of the many other studies in this area. Many of them have been reviewed by Child (5). They are not cited here specifically because: (a) of the need for economy of space; (b) they are not centrally germane; and (c) the method of analysis proposed would be essentially the same as in the studies cited.

guish. Superficial consideration of these results would seem to indicate that the anxiety patients met the requirements of the situation more efficiently than the normals. However, closer examination of the instructions to the subjects casts considerable doubt on such a conclusion. The subjects were told that it was a test of their sweating activity, that the experimenter wanted them to relax as much as possible, and that in order to help them to relax and keep their minds off extraneous matters, they would be shown a group of nonsense syllables which they were to read aloud. It is true that the experimenters wanted to force the subjects to make an arbitrary<sup>3</sup> association between two events contiguous in time: the nonsense syllable "kax" and the buzzer. But the subjects were not told this, and it is not stated that any of them discovered it. Now, if we assume that the two groups were equally motivated to cooperate with the experimenter, it becomes apparent that the normals fulfilled the requirements of the task, as, presumably, they saw them most efficiently. For them, the buzzer was extraneous stimulation which, according to the experimenter's instructions, they were supposed to ignore.

The fact that the normals eventually were also conditioned gives rise to some interesting speculation. Is it possible that the normals were conditioned only after they became bored with the task, or sufficiently disturbed by the repeated soundings of the buzzer? Such a possibility should be given serious consideration. It seems reasonable to suppose that the anxiety patients were generally in a more diffuse state, less able to concentrate. The assumption that, in such a state, an individual is more prone to make *arbitrary* associa-

tions between events contiguous in time and space is tenable on the basis of the experimental data available. The normals condition too, when the monotony of the task disturbs their integrated functioning sufficiently to make them "victims" of contiguity, arbitrarily arranged by the experimenter. Some of the data of Taylor (18) and Spence and Taylor (16) appear to support this notion. They have plotted the mean number of conditioned eyeblink responses of their anxious and nonanxious subjects as a function of succeeding blocks of 10 trials. Taylor's curves show that the nonanxious subjects give practically no CR's for the first 20 trials, and only after 60 trials does the slope of the nonanxious curve begin to approximate the slope of the anxious curve. The Spence and Taylor curves are similar although not quite so spectacular.

There is, of course, a substantial psychological difference between being an unwitting "victim" of contiguity and *learning* by contiguity, which is often a task requirement, as in serial learning. There is a difference between memorizing something, even a list of nonsense syllables, for some purpose, as against making spontaneous, arbitrary associations between contiguous events which have no inherent connection with each other. The latter is reminiscent of the conditioning apparently involved in phobia formation.

The question arises whether the task requirements in the Welch and Kubis experiment could be changed by a change in the instructions, and so effect a reversal of the results. If the subjects were instructed that the situation contains a problem of contiguity, such a reversal might well be brought about. In other words, it would be predicted, on the basis of the present analysis, that the normals would "solve" the problem sooner, and it could be expected that

<sup>3</sup> Arbitrary because there is no inherent or logical connection between "kax" and the buzzer.

this would be reflected in more rapid GSR "conditioning." Under these conditions, of course, the experiment is no longer of the classical type. It might be characterized more accurately as a problem-solving situation.<sup>4</sup>

In sum, then, it has been proposed that efficiency in learning can be measured if the task requirements can be specified. Efficiency in learning is characterized by a tendency to seek for orderly relationships (except when the subject is instructed otherwise), and to resist arbitrary associations. These can be induced most easily when the organism is in a diffuse state, either because of the existence of some degree of psychopathology, or because of the inherent senselessness of the task.

#### EFFICIENCY IN MOTIVATION: TASK ORIENTATION AND INTERPERSONAL COOPERATIVENESS

The purpose of this section is to adumbrate possible developments in this area, rather than attempt to deal exhaustively with it. Utilizing the concept of efficiency as defined above, the initial approach must be toward a specification of environmental requirements. Aside from the so-called primary drives, however, such specification for the field of motivation constitutes a gigantic problem beyond the scope of this paper. Nevertheless, at least two very general requirements can be assumed, although they do not exhaust the possibilities by any means. As Wertheimer (23) and Asch (2) have pointed out, social existence and creative achievement require a certain degree of interpersonal cooperativeness and task involvement respectively. Such assumptions may run counter to what Asch has labelled the "private profit" theory of society," but they seem en-

tirely tenable, indeed necessary, in view of the facts of social life and the phenomenology of productive thinking.

Granted these general environmental requirements, what are the implications for experimental work in psychopathology? The proposed concept of efficiency would necessitate the examination or control of the subjects' motives with respect to these requirements. The degree of concordance of the motives with the task requirements would presumably determine the efficiency of the relevant behavior. Unfortunately, published experimental data centered on this problem are unavailable. The general findings that ego involvement often increases productivity are not central here because they are based on faulty analyses in at least two respects: (a) ego involvement is generally defined in terms of interest in the task; task-orienting instructions seem designed to decrease interest. In such cases, it cannot be assumed that the motivation of the "ego-involved" subjects is *egocentric*. (b) Even when the instructions do not contain this defect, the tasks themselves are not constructed so that they form inherently organized wholes. When the tasks involved are sensible and have objective internal organization, we should expect ego-oriented individuals, since they are more diffuse with respect to the general requirement of task orientation, to behave more diffusely and therefore to perform more poorly than task-oriented individuals. When the tasks have an arbitrary character, as in classical conditioning, ego-oriented individuals should perform "better." In the latter case, the better performance is actually the more inefficient in relation to the task requirements.

An unpublished experiment by Birch<sup>5</sup> appears to provide an ingenious circum-

<sup>4</sup> In this connection, see Asch's analysis of Watson and Raynor's experiment on conditioned fear in infants (2, pp. 99-101).

<sup>5</sup> Birch, H. Personal communication, 1953.

vention of the difficulties outlined above. Three different groups of subjects were asked to solve Wertheimer's 9-dot problem. The actual experimenter was one of Birch's students. One group (A) was told that the test measures capacity for graduate work, and that departmental recommendations would be based on the results. In another group (B) this test orientation was hinted at, but cooperation with the experimenter was emphasized. The third group (C) was told that the experimenter was getting the data for his professor, who was a horrible taskmaster; the entire emphasis was on requesting the subject to do his best for the sake of the unfortunate student experimenter. This last type of instruction should result in maintaining the subjects' interest, but on a cooperative, rather than egocentric or competitive level. The results show no significant differences between the groups in number of solutions achieved. However, systematic differences were found in the number of times subjects drew lines to extend beyond the boundaries set by the dots. The groups ranked in the order CBA from most to least. Since going beyond the boundaries set by the dots is the first prerequisite for a solution, it may be that such a measure is a more accurate indication of the degree of meeting task requirements than actual solution. The latter measure may be confounded with other variables, e.g., ability in spatial perception, specific experience, etc.\*

Clinical observation also indicates the relevance of evaluation of a patient's motivational structure with respect to the assumed environmental requirements

\*Of course, both the independent and dependent variables may be somewhat confounded here: the former with anxiety, the latter with the same factors which are thought to disqualify number of solutions as an appropriate measure. The evidence from this experiment must therefore be evaluated with caution.

of cooperation and task-oriented interest in his surroundings. Perhaps the most common characteristic of schizophrenics is withdrawal from social relationships. Thus, schizophrenia represents a high degree of psychopathology. Schizophrenics are oriented away from all social requirements. Many psychoneurotics are characterized by hostile competitiveness. Therefore, this is a milder degree of psychopathology, since social relationships are at least considered, but they are not dealt with efficiently.

A rather incisive analysis of the effects of egocentricity on the perception of a social situation was made by Wertheimer (23, ch. 4). In the same place, Wertheimer also tells of the positive effects of changing a competitive relationship into a cooperative one in the case of a game of badminton. Wertheimer's materials suggest many experimental hypotheses in this field, but controlled studies are disappointingly scarce.

To summarize this section, necessarily sketchy because of the scarcity of controlled experimentation, it is proposed that the concept of efficiency can be utilized in the area of motivation. On the assumption that cooperativeness and task involvement are general environmental requirements, it is predicted that inefficient behavior would be a function of the degree of incongruity of an individual's motives with respect to these requirements. It should be clear that congruity and incongruity as descriptive of motivation are parallel to focused and diffuse in descriptions of motor activity. Thus, the concept of efficiency is held constant across all the areas discussed to this point.

#### EFFICIENCY AS A CENTRAL EGO FUNCTION

Within the framework of general personality theory, efficiency may be re-



garded as reflecting a central ego function. In the simplest terms, ego is here understood as having to do with the direction of the organism in its interaction with the environment.<sup>7</sup> Efficiency, then, is not a trait in the sense of permanence. Nor is it part of temperament or character, as these terms are commonly understood. Rather, the degree of efficiency of behavior reflects the degree with which the ego manages to focus the organism's attention and action on the task requirements. Efficiency, therefore, should be affected by various environmental changes, as has been indicated above.

#### DOES EFFICIENCY IN MEETING TASK REQUIREMENTS IMPLY EQUATING PSYCHOLOGICAL HEALTH WITH SOCIAL CONFORMITY?

While possible application of the concept of efficiency to everyday situations is beyond the scope of this paper, the question above intrudes itself rather insistently because of the superficial similarity between "meeting task requirements" and conformity to majority opinion or behavior. In fact, however, they have little in common. A task requirement involves an objective description of the structure of a situation, and what is demanded by it, in terms of a total gestalt. Majority opinion and other social forces may be significant aspects of the situation, but are not necessarily all of it. Indeed, efficient behavior may consist in going counter to the majority.

Many examples of this could be culled from everyday life situations. A pertinent experimental illustration is provided by Asch (2, ch. 16) in his work on group pressure. A naive subject is introduced into a group of the ex-

perimenter's confederates. The subjects are presented with a group of three lines and with a standard. Their task is to report which one of the three is equal in length to the standard. Under control conditions, this can be done with almost perfect accuracy. In the experimental condition, where the confederates speak first, 20 to 30 per cent of the responses conform to the majority when the latter is instructed to pick the wrong line. How is this behavior to be evaluated? Clearly, it is inefficient with respect to the instructions given by the experimenter. The yielding subjects have allowed other factors to affect their reports. Efficient behavior in this case consists in focusing on the requirement to give the correct response rather than on majority opinion. In relation to psychological health, a subject is healthy in this case to the degree that he resists social pressure.<sup>8</sup> In other situations, of course, overt conformity to majority opinion may be necessary, but these need not be gone into here. In any case, it should be clear that efficiency in meeting task requirements and sheer conformity, or passive adjustment, are not the same thing.

#### SUMMARY

The main purpose of this paper was to outline a descriptive conception of psychological health and psychopathology, conceived as a continuum. It was proposed that this continuum be defined in terms of the comparative efficiency in meeting task requirements. Analysis indicated that efficiency is a meaningful parameter only when task requirements can be specified objec-

<sup>7</sup> For a more complete discussion of the nature and need for a concept of the ego, see (2, ch. 10).

<sup>8</sup> Of course, this may not be true in any individual case. The motivation for remaining independent may be egocentric; contrariwise, yielding may be based on too subtle an evaluation of the situation, rather than on egocentric motives. Nevertheless, one would expect the relationship to hold generally.

tively. When this can be done, it is hypothesized that efficiency ( $E$ ) is a function of the ratio of focused ( $F$ ) to diffuse ( $D$ ) activity, and of productivity ( $P$ ), or performance:  $E = f(F/D, P)$ .  $F$  activity is defined as activity directly relevant to the task requirements;  $D$  activity is that which is irrelevant to the task requirements.

The concept of efficiency was then utilized in an analysis of some of the data on conditioning under anxiety. It was pointed out that the data in this area do not appear to be specific to anxiety. Rather, increased rates of conditioning are found with increasing degrees of psychopathology, or diffusion. Classical conditioning was then analyzed as a situation requiring arbitrary associations, and it was assumed on the basis of existing data that such associations are facilitated in diffuse states. The more rapid conditioning of pathological groups in such conditions was seen as actually inefficient behavior. It was pointed out that the results in intrinsically organized tasks showed normals to be more efficient.

An attempt was also made to analyze some aspects of motivation from the point of view of efficiency. It was hypothesized that egocentric motivation was inefficient because of the general environmental requirements for task orientation and cooperation. Thus, egocentric motivation would lead to poor performance in sensible tasks, as defined above.

Efficiency was conceptualized as a central ego process, subject to change by various situational factors. It was shown that it was not synonymous with conformity. At the same time, no general application to everyday life situations was attempted, except to indicate that the present proposal did not appear to violate current inferences from clinical observation.

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